COTTON MILL MATHEMATICS

QUIGLEY AND SMITH

COTTON MILL MATHEMATICS

BY

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TO

James Fayette Cannon

THROUGH WHOSE SPONSORSHIP THE
PREPARATION OF THIS BOOK
WAS MADE POSSIBLE; IT IS
SINCERELY DEDICATED

FOREWORD TO INSTRUCTORS

Aim and General Plan of the Book

This book has been prepared for use in the night, part-time and day textile classes of cotton mill communities and plants. It is written for young people of working age and adults already familiar in a general or practical way with the cotton mill, who have had little or no training in mathematics, but who have the ambition and determination to forge ahead in this great and growing industry.

The book, therefore, begins with elementary arithmetic and aims to carry the learner through many of the everyday, elementary, but somewhat complicated, calculations necessary in the usual plain goods mill. Part I uses textiles as an apperceptive basis for imparting the fundamental conceptions and processes of mathematics. Part II aims to teach the technical textile mathematics of the usual plain goods mill. Part I is arranged in the usual logical manner of common arithmetic. Part II is arranged according to textile subjects.

Pedagogically, it is aimed to develop independence of thought rather than the blind following of rules, to the end that the learner may be able to think his way through any mathematical problem arising in the carding, spinning and weaving departments. With this in view, it is desirable to develop in the pupil the ability to derive formulas, as well as to use them, and,

consequently, no attempt has been made to present all the calculations necessary, even in a plain goods mill.

Detailed Plan and Use of the Book

Relation of Part I to Part II. Part II is based on an analysis of the calculations necessary in the mill. Only such matter as is essential and preliminary to part II of the book has been included in part I. Part I, therefore, represents an analysis of the fundamental mathematical conceptions involved in practical mill calculations.

Sequence of Chapters in Part I and Part II. Following is a suggestive sequence for the use of this book by members of a class wishing to specialize, as between carding, spinning or weaving:

Carding	Spinning	Weaving
Part I, chapters I to XX	Part I, chapters I to XX	Part I, chapters I to XX
Part II, chapter I	Part II, chapter I	Part II, chapter I
" " III	" " II	" " II
" " IV	" " III	" " IV
" " VI	" " IV	" " V
" " VII	" " X	" " XII
" " VIII	" " XI	
" " IX		

In part II, chapter VI, Picker Calculations, is a preliminary to chapter VII, Card Calculations, chapter VIII, Drawing Frame Calculations, and chapter IX, Fly Frame Calculations, and must precede them. Chapter X, Spinning Frame Calculations, is preliminary to chapter XI, Twister, Spooler and Warper Calculations.

Independence of Chapters, Part II. However, chapters X and XI, part II, are developed independently of the card-room chapters VI, VII, VIII and IX. Chapter XII, Loom Calculations, is independent of any other chapter in part II, and may follow directly after chapter XX, part I.

Omission of Chapters, Part I. Not all of part I is essential to every chapter of part II. In night-school instruction it will not be necessary, and sometimes will be undesirable, to insist upon the completion of part I before part II is attempted. An examination of the book will make evident the following: chapter XVIII, part I, Square Root, is not a prerequisite to chapters XIX and XX, part I, nor chapters I, II, III, V, VI, VII, VIII and XII, part II. Chapter XVI, Percentage, is not prerequisite to chapters XVII, XVIII, XIX and XX, part I, nor chapters I and II, part II. Chapter XX, part I, Pulleys, Gears, Belts and Levers, is not prerequisite to chapters I, II, III, IV and V, part II.

Omission of Matter within Chapters. Part I contains an abundance of practical problems taken from the three departments of the mill. It may be wise to assign to a member of the class only problems from the department in which he is immediately interested.

Except for the derivation of lay calculation formulas and, to some extent, twist calculation formulas, measures of volume in chapter XVII, part I, may be omitted. Except for the satisfaction of knowing that one can find them if necessary, the finding of square roots of imperfect squares in chapter XVIII, part I, may be omitted and the instruction confined to square

roots of perfect squares and the use of square root tables.

In part II, chapter I, Roving and Single Yarn Calculations, a man from the weave room will need to study yarn numbering, but may have no present interest in studying about roving. Hence, for him all roving problems may be omitted.

Reflection upon the interest and needs of the individual pupil and an examination of the text will reveal other instances of this kind.

Sequence within Chapters. Before assigning lessons on any subject in this book, instructors should look over the problems and the manner of presentation for the reason that many of the questions and problems are arranged in an intentional sequence of learning difficulties.

Individual Instruction and Progression. The instruction must be shaped to the individual's need, interest and capacity. For this reason, in night classes the instruction, especially in part I of the book, should be largely on an individual basis. The fullness of the explanations in the text is intended to reduce to a minimum the necessity for the duplication of oral instruction and, consequently, to promote the ease of giving individual instruction. Some grouping of pupils, however, is possible and often makes for efficient teaching and conservation of the teacher's energy. As soon as the night pupil has *barely* mastered the use of an elementary mathematical process, it is usually better to pass him on to the next process, since his subsequent work will afford him abundant practice in processes previously encountered.

Vitalizing of Instruction. While every problem in the book represents a practical mill situation, nothing can vitalize the instruction in mill mathematics so much as bringing to the class live problems from the mill and taking the class to the mill. Copies of the cotton, production, waste and other reports should be brought to the class as problems in addition, subtraction, percentage and the other mathematical operations involved in completing these reports. The overseers should be asked for live, practical problems. The work of the class should be made as concrete as possible. For instance, in the initial instruction in yarn numbering, the reel and balance should be brought to the class. If the subject in the class is the draft constant of a card, arrangements should be made to hold the class at the card.

In order to vitalize the instruction in part I, some problems may be borrowed from part II. Actual draft problems, for instance, of the picker, card and drawing frame from chapter III, part II, may be brought forward for use in the study of the division of decimals. Indeed, there will be found in part I of the book many problems which as regards textile content logically belong in part II, but which are introduced into part I for their interest-stimulating value. For the same reason, there have been placed in the earlier chapters of part I several problems which as exercises in the handling of numbers conform to their places, but which might be solved more easily in later chapters of part I.

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This book being an outgrowth of Mr. Smith's many years of practical mill and night-school teaching experience, a large proportion of the problems originated in his daily work and have been repeatedly checked by his classes. And while all other problems have been triple checked and the book has been proof-read five times, the citation of errors and frank criticism of any phase of the book will be greatly appreciated.

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COTTON MILL MATHEMATICS

PART ONE

CHAPTER I

READING NUMBERS

All kinds of numbers are used in a cotton mill. Every day many calculations are made involving the use of numbers from very small ones to very great ones. It is, therefore, very important that right at the start of your adventure into cotton mill calculations you learn how to read numbers.

Digits. All numbers are composed of *digits.* The digits are 0, 1, 2, 3, 4, 5, 6, 7, 8 and 9.

Consider the number 6,259,347. It is composed of seven digits. The last or right-hand digit in any number is called the *units* digit. In this case 7 is the units digit. The next to the last digit is called the *tens* digit. In this case 4 is the tens digit. The second from the last digit is called the *hundreds* digit. In this case 3 is the hundreds digit. The next digit is called the *thousands* digit. In this case 9 is the thousands digit. Then next is the *ten thousands* digit which is 5. Next is the *hundred thousands* digit which is 2. Next is the *millions* digit which is 6. Oftentimes, though not always, commas are put into a number to separate the digits into groups of three, as in this case.

This number is read: six million, two hundred fifty-nine thousand, three hundred forty-seven. In other words, to read a num-

ber we separate the last three digits off from the rest by a comma, then the next three digits, and so on until we have the whole number separated into groups of three digits. Then we read the first digit or group of digits just as though there were no other digits in the number. In this case there is only one digit in the first group. So we simply say "six." Then we say the name of the digit, "million." Then we read the next group of digits just as though there were no other digits in the number. We say "two hundred fifty-nine." And then we say the name of the last digit in the group, "thousand." Then we read the last group, "three hundred forty-seven," but do not call the name of the last two digits.

PROBLEMS. *Put in the commas and read the following numbers:*

1. 122.	**7.** 11122.	**13.** 1111122.
2. 236.	**8.** 32236.	**14.** 6532236.
3. 999.	**9.** 99999.	**15.** 9999999.
4. 1122.	**10.** 111122.	**16.** 11111122
5. 2236.	**11.** 532236.	**17.** 76532236.
6. 9999.	**12.** 999999.	**18.** 99999999.

After the millions digit comes the *ten millions* digit, then the *hundred millions* digit and then the *billions* digit.

Read the following numbers:

19. 143256793.	**21.** 769832456.	**23.** 11456666732.
20. 650763941.	**22.** 3896743226.	**24.** 27567891429.

If any group of digits has a zero, 0, in it, we do not say anything at all. Consider the number 709,690,032,001. We read it like this: seven hundred nine billion, six hundred ninety million. thirty-two thousand, one.

Read the following numbers:

25. 1001.

26. 10001.

27. 100000.

28. 500009.

29. 1000000.

30. 900000000.

31. 901020304.

32. 9000000002.

33. 100001001001.

Write in digits the numbers that are given in the following statements:

34. Alabama has one million two hundred ninety-four thousand five hundred twelve cotton spindles.

35. Connecticut has one million three hundred twenty-five thousand eight hundred fifty-six cotton spindles.

36. Georgia has two million six hundred eighty-two thousand seven hundred thirty cotton spindles.

37. Maine has one million one hundred thirty-seven thousand six hundred fifty-one cotton spindles.

38. Maryland has one hundred twelve thousand twenty-four cotton spindles.

39. Massachusetts has eleven million two hundred twenty-two thousand seven hundred forty-one cotton spindles.

40. Mississippi has one hundred seventy-eight thousand five hundred eight cotton spindles.

41. New Hampshire has one million three hundred eighty-four thousand seven hundred fifty-seven cotton spindles.

42. New Jersey has four hundred forty thousand five hundred sixty cotton spindles.

43. New York has one million two hundred thirty-four cotton spindles.

44. North Carolina has five million four hundred sixty-three thousand five hundred forty-seven cotton spindles.

45. Pennsylvania has one hundred sixty-four thousand five hundred seven cotton spindles.

46. Rhode Island has two million eight hundred thirty-seven thousand nine hundred three cotton spindles.

47. South Carolina has five million one hundred seven thousand thirty-eight cotton spindles.

48. Tennessee has four hundred thirty-seven thousand one hundred sixty-eight cotton spindles. .

49. Texas has one hundred seventy-five thousand one hundred four cotton spindles.

50. Vermont has one hundred forty-four thousand eight hundred eight cotton spindles.

51. Virginia has six hundred fifty-four thousand seven hundred eighty-five cotton spindles.

52. The United States has thirty-six million two hundred sixty thousand one cotton spindles.

53. Canada has one million three hundred seventy-five thousand cotton spindles.

54. England, Scotland, Ireland and Wales have fifty-six million five hundred eighty-three thousand cotton spindles.

55. The world has a total of one hundred fifty-seven million seven hundred sixty-three thousand cotton spindles.

These figures are from the Report of the U.S. Department of Commerce, 1923.

CHAPTER II

ADDITION OF WHOLE NUMBERS

The process of finding a number equal to two or more numbers taken together is called *addition*. Thus, to *add* 3 yards of cloth and 6 yards of cloth is to find the number of yards in both pieces taken together.

To signify that numbers are to be added together, we use the sign + which is read "plus." We could signify that the above pieces of cloth are to be added by writing thus: 3 yards + 6 yards. We would read it like this: "three yards plus six yards."

To signify that the numbers when added together are the same as, or equal to, another number, we use the sign = which is read "equal" or "equals," whichever is proper. Thus, in the above case, 3 yards + 6 yards = 9 yards. We would read it thus: "three yards plus six yards equal nine yards."

When we add two or more numbers together we find their *sum*. Thus, the sum of 3 yards and 6 yards is 9 yards.

Addition of Numbers Containing One Digit

Example: *Find the sum of* 2, 3 *and* 5.

$$2 + 3 + 5 = 10.$$

Example: *Find the sum of* 5, 6 *and* 7.

$$5 + 6 + 7 = 18.$$

Problems. *Find the sum of the following, using plus and equal signs:*

1. 2 and 3.	**4.** 5 and 6.	**7.** 8 and 9.	**10.** 6, 7 and 8.
2. 3 and 4.	**5.** 6 and 7.	**8.** 9 and 9.	**11.** 7, 8 and 9.
3. 4 and 5.	**6.** 7 and 8.	**9.** 4, 5 and 6.	**12.** 9, 9, 9 and 0.

Addition of Numbers Containing More than One Digit when the Sum of Similar Digits Does Not Exceed Nine

The easiest way in which to add numbers of more than one digit is to place the numbers under each other, keeping the units digit of each number in a straight line, the tens digits in a straight line, the hundreds digits in a straight line and so on. Suppose we wish to add 32, 21 and 16. We would do it as follows:

$$\begin{array}{r} 32 \\ 21 \\ \underline{16} \end{array}$$

$$\begin{array}{r} 32 \\ 21 \\ \underline{16} \\ 9 \end{array}$$

Adding the units digits $(6 + 1 + 2)$ first, the sum is 9. Place the 9 below the line.

$$\begin{array}{r} 32 \\ 21 \\ \underline{16} \\ 69 \end{array}$$

Adding the tens digits $(1 + 2 + 3)$, the sum is 6. Place the 6 below the line.

Therefore, the sum of $32 + 21 + 16 = 69$. The answer is 69.

Example: *Find the sum of* 22, 36 *and* 41.

$$\begin{array}{r} 22 \\ 36 \\ \underline{41} \\ 99 \end{array}$$

Answer: 99.

Problems:

13. Add 11, 23 and 51.
14. Find the sum of 13, 26 and 40.
15. What is the sum of 11, 31, 26 and 10?
16. What does 1, 2, 11, 22, 21 and 32 equal?
17. What does 2, 21, 30 and 136 equal?
18. How much is 23 plus 105 plus 201 plus 670?

Addition of Numbers of More than One Digit when the Sum of Similar Digits is Greater than Nine

Suppose we wish to add 540, 449 and 331. We proceed as we did before.

$$\begin{array}{r} {\scriptstyle 1} \\ 540 \\ 449 \\ \underline{331} \\ 0 \end{array}$$

Adding the units digits (1 + 9 + 0) first, the sum is 10. Place the 0 of the 10 below the line and place the 1 of the 10 above the tens digits.

$$\begin{array}{r} {\scriptstyle 11} \\ 540 \\ 449 \\ \underline{331} \\ 20 \end{array}$$

Add the tens digits and the 1 we have placed above the tens digits (3 + 4 + 4 + 1). The sum is 12. Place the 2 of the 12 below the line and the 1 of the 12 above the hundreds digits.

$$\begin{array}{r} {\scriptstyle 11} \\ 540 \\ 449 \\ \underline{331} \\ 1320 \end{array}$$

Add the hundreds digits and the 1 we have placed above the hundreds digits (3 + 4 + 5 + 1). The sum is 13. Place the 13 below the line. Answer: 1320.

Example: *Six laps are delivered from the picker weighing* 40 *pounds,* 42 *pounds,* 41 *pounds,* 43 *pounds,* 40 *pounds and* 44 *pounds. What is the total weight of the six laps?*

$$\begin{array}{r} {\scriptstyle 1} \\ 40 \\ 42 \\ 41 \\ 43 \\ 40 \\ \underline{44} \\ 250 \end{array}$$

Answer: 250 pounds.

19. From this cut board find the number of cuts woven each day on section 1. Also, find the number of cuts woven by each weaver during the week. And then find the total production of section 1 for the week by adding the cuts woven each day. Then compare this sum with the sum of the cuts woven by each weaver. If these last two sums are equal, you have added correctly.

SECTION NO. 1	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
J. C. Smith..............	10	7	10	12	16	18
H. C. Jones.............	2	18	14	19	3	26
L. M. Simmons.. ...	14	1	9	21	2	20
S. O. Johnson...	5	14	7	30	16	—
B. H. Thomas..........	2	8	11	10	22	14
A. B. Harris.............	6	21	5	2	8	32
D. M. Young...........	1	16	21	5	19	7
R. F. Collins	6	12	14	12	10	18

20. If there are 840 looms in room No. 1 and 810 in room No. 2 and 290 in room No. 3, how many looms in the mill?

21. If a weaver weaves 660 yards of cloth the first day, 702 the second day and 967 the third day, how many yards did he weave in the three days?

22. The sizing tallow report for the week is as follows: Monday, 398 pounds; Tuesday, 310 pounds; Wednesday, 356 pounds; Thursday, 324 pounds; Friday, 342 pounds; Saturday, 88 pounds. How many pounds were used during the week?

23. In a certain mill, 1080 looms make sheeting, 460 looms make drills, 380 looms make sateen. How many looms in the mill?

24. A buyer buys three bales of cloth, the first containing 1128 yards, the second 1242 yards and the third 1080 yards. How many yards in all?

25. A mill sold five bales of thread waste weighing as follows: the first bale 622 pounds, the second 608 pounds, the third 684 pounds, the fourth 700 pounds and the fifth 667 pounds. How many pounds did the five bales weigh?

26. A mill sells a certain amount of sheeting for $7524, drills for $8241, twills for $1260, sateens for $2408 and print cloth for $3008. What was the amount of this sale?

27. The weekly report of a cloth room is as follows: Monday, baled 77,600 yards; Tuesday, 81,004 yards; Wednesday, 74,666 yards; Thursday, 80,422 yards; Friday, 78,948 yards; Saturday, 30,024 yards. How many yards are there in all?

28. The working force of a weave room consists of 3 second hands, 2 head fixers, 28 loom fixers, 104 weavers and 42 job hands. How many hands in all?

29. A mill purchased five boxes of drop wires, the first box containing 50,000, the second 62,420, the third 30,020, the fourth 28,960 and the fifth 40,000. How many drop wires in the five boxes?

30. An intermediate picker produced the following amounts of 14-ounce lap: Monday, 2271 pounds; Tuesday, 2286 pounds; Wednesday, 2296 pounds; Friday, 2285 pounds; Saturday, 1149 pounds. How many pounds did this picker produce in a week?

31. A spinning room report showed the following amounts of warp yarn spun during the week: number 13 yarn, 15,160 pounds; number 12 yarn, 32,082 pounds; number 21 yarn, 14,900 pounds; number 23 yarn, 13,550 pounds; number 11 yarn, 13,162 pounds; number 9 yarn, 22,818 pounds. How many pounds of warp were produced?

32. A spinning overseer's report for the week showed the following made during the week: 111,672 pounds of warp yarn; 94,100 pounds of filling yarn; 247 pounds of spooler waste; 18 pounds of filling waste; 2714 pounds of cleaners' waste; 184 pounds of beam waste. How many pounds of yarn were produced and how many pounds of waste?

CHAPTER III

SUBTRACTION OF WHOLE NUMBERS

The process of finding the difference between two numbers is called *subtraction.* Thus, to *subtract* 3 yards from 9 yards is to find the difference between 3 yards and 9 yards.

To signify that one number is to be subtracted from another number, we write the larger number, then write the sign $-$, which is read "minus," then write the smaller number. We use the equal sign as we did in addition. Thus: 9 yards $-$ 3 yards $=$ 6 yards. This would be read "9 yards minus 3 yards equal 6 yards."

Subtraction may also be called *taking away.* Thus, if we have 9 yards and take away 3 yards, we have 6 yards left.

Simple Subtraction

Example: *Subtract* 7 *from* 8.

$$8 - 7 = 1.$$

Example: *Subtract* 7 *from* 18.

$$18 - 7 = 11.$$

Problems. *Find the difference between the following numbers, using the signs for minus and equal:*

1. 3 and 7. **3.** 13 and 2. **5.** 19 and 4. **7.** 69 and 6.

2. 5 and 9. **4.** 15 and 3. **6.** 25 and 2. **8.** 117 and 5.

9. If we take away 7 from 19, what is left?

10. 5 subtracted from 48 equals what number?

11. 0 subtracted from 25 equals what number?

12. What is the difference between 41 and 0?

13. 9 subtracted from 9 equals what number?

Find the difference between the following numbers:

14. 12 and 8.	**17.** 7 and 11.	**20.** 8 and 17.
15. 6 and 13.	**18.** 8 and 13.	**21.** 9 and 18.
16. 9 and 15.	**19.** 14 and 7.	**22.** 10 and 4.

Subtraction of Numbers Involving Subtraction of Similar Digits from Each Other

Usually in subtracting numbers of more than one digit, it is easiest, especially while you are still learning, to write the larger number above the smaller number. Suppose we wish to subtract 21 from 35. We should do it as follows:

$$\begin{array}{r} 35 \\ \underline{21} \end{array}$$

Starting with the units digits, subtract the 1 from the 5. The difference is 4. Place the 4 below the line.

$$\begin{array}{r} 35 \\ \underline{21} \\ 4 \end{array}$$

Next, subtract the tens digit. The difference is 1. Place the 1 below the line.

$$\begin{array}{r} 35 \\ \underline{21} \\ 14 \end{array}$$

Therefore, $35 - 21 = 14$. Answer: 14.

Problems. *Find the difference between the following numbers:*

23. 27 and 12.	**25.** 36 and 26.	**27.** 79 and 35.
24. 35 and 24.	**26.** 45 and 15.	**28.** 199 and 98.

Subtraction of Any Numbers

Suppose we wish to subtract 469 from 658. Place the larger number above the smaller.

$$\begin{array}{r} 658 \\ \underline{469} \end{array}$$

Not being able to subtract 9 from 8, we will *borrow* 10 from the tens digit column, thereby reducing the 50 to 40 (that is, reducing the 5 to a 4), and increasing the 8 to 18, and then subtract the 9 from the 18 and place the difference, 9, below the line, like this:

$$\begin{array}{ccc} & 4 & \\ 6 & \cancel{5} & {}^{1}8 \\ 4 & 6 & 9 \\ \hline & & 9 \end{array}$$

Again, we see we cannot subtract the 60 in the tens digit column from the 40 above it (that is, the 6 from the 4). So we borrow 100 from the hundreds column, thereby reducing the 600 to 500 (that is, reducing the 6 to 5), and increasing the 40 to 140 (that is, increasing the 4 to 14).

Then, we subtract the 60 from the 140 (that is, the 6 from the 14) and place the difference, 80 (that is, 8), below the line, like this:

$$\begin{array}{ccc} 5 & 14 & \\ \cancel{6} & \cancel{5} & {}^{1}8 \\ 4 & 6 & 9 \\ \hline & 8 & 9 \end{array}$$

Then, we subtract the 400 from the 500 (that is, the 4 from the 5) and place the difference, 100 (that is, 1), below the line, like this:

$$\begin{array}{ccc} 5 & 14 & \\ \cancel{6} & \cancel{5} & {}^{1}8 \\ 4 & 6 & 9 \\ \hline 1 & 8 & 9 \end{array}$$

Therefore, 658 − 469 = 189.

EXAMPLE: *If a spinning room has* 26,614 *spindles, and* 11,125 *spindles are running warp yarn and the rest of them are running filling yarn, how many are running filling yarn?*

$$\begin{array}{lccc} & 5 & 10 & \\ 26 & \cancel{6} & \cancel{1} & {}^{1}4 \\ 11 & 1 & 2 & 5 \\ \hline 15 & 4 & 8 & 9 \end{array}$$

Answer: 15,489 spindles are running filling yarn.

29. A mill has 940 drill looms and 690 sheeting looms. How many more drill looms than sheeting looms?

30. From a bale of burlap containing 1034 yards, 360 yards have been cut. How many yards remain in the bale?

31. A mill buys 12,000 pounds of sizing tallow and uses 7580 pounds of it. How many pounds remain?

32. 62,847 pounds is the weekly production of a certain spinning room. If 38,117 pounds of this are warp, how much is filling?

33. A cut of a certain style of cloth weighs 14 pounds. If it contains 8 pounds of sized warp, what is the weight of the filling?

34. A cut of a certain style of cloth weighs 15 pounds. The filling weighs 6 pounds. What is the weight of the warp and sizing?

35. The cut marks on the warp for a certain style of cloth are 62 yards apart as the warp comes from the slasher. The cut marks in the woven cloth are 59 yards apart. How much has the warp contracted, or shrunk, during weaving?

36. The test report of a certain card showed that it made 964 pounds of sliver in a certain week. If 1013 pounds of lap were fed into the card during the week, how many pounds of waste did the card make?

37. 25,000 pounds of cotton were manufactured into cloth, making 21,987 pounds of cloth. How many pounds were lost in manufacturing?

38. Arkwright patented the first ring spinning frame in the year 1769. How many years has it been in use up to 1927?

39. In 1894 the present type of automatic loom was put on the market. How many years has it been in use up to 1927?

40. In 1914 a mill paid $299 for a certain amount of cotton. In 1919 it paid $1801 for the same amount. How much more did the same amount cost in 1919 than it did in 1914?

41. An order comes to the mill for 251,570 yards of a certain style of cloth. The mill warehouse has 544,000 yards of the cloth in storage. After filling the order, how many yards will be left in storage?

42. An order calls for 208,000 yards of a certain style of cloth. 199,788 yards have been made. How many yards must be made to complete the order?

43. The weights of ten section beams before being slashed are as follows: 478 pounds, 475 pounds, 479 pounds, 471 pounds, 474 pounds, 475 pounds, 476 pounds, 474 pounds, 474 pounds and 477 pounds. After being slashed, this same yarn has a total weight of 5206 pounds. How many pounds of sizing has the slasher put into the yarn?

CHAPTER IV

MULTIPLICATION OF WHOLE NUMBERS

Multiplication, or *multiplying*, is a short method of adding. Thus, to find out how many yards there are in three pieces of cloth if each piece contains 2 yards, we can *add*, like this: 2 yards + 2 yards + 2 yards = 6 yards. Or we can shorten this by *multiplying*, using the multiplication sign, $\times$, like this: 3×2 yards = 6 yards. This would be read as follows: "3 times 2 yards equals 6 yards," or like this: "3 multiplied by 2 yards equals 6 yards," or like this: "2 yards multiplied by 3 equals 6 yards," or like this: "2 yards times 3 equals 6 yards."

The result of multiplying is called the *product*. Thus: "6 is the product of 2 times 3"; or "6 yards is the product of 3 yards multiplied by 2"; or "the product of 2 times 3 yards is 6 yards." Or you may say it any way that makes common sense.

The preceding problem may be written in any one of the following ways:

3×2 yards = 6 yards.
2 yards $\times 3$ = 6 yards.
6 yards = 3×2 yards.
6 yards = 2 yards $\times 3$.

Hence, we see that it is shorter to multiply 2 yards by 3 than to add 2 yards plus 2 yards plus 2 yards, provided we already know that 2 times 3 is 6. And the only way to find out what 2×3 is, is to add $2 + 2 + 2$.

EXAMPLE: *Find the product of* 6×4.

$4 + 4 + 4 + 4 + 4 + 4 = 24$ or
$6 + 6 + 6 + 6 = 24$.

EXAMPLE: *Find the product of* 7×4.

From the preceding example we see that $6 \times 4 = 24$. Therefore, 7×4 must $= 6 \times 4 + 4 = 28$.

PROBLEMS: *Find the product of the following numbers. Do as little work as possible to find the products. Look closely and you may see that the product of one problem will make another one easy. For instance, the answer to problem* 1 *will help you with problem* 2, *and the answer to problem* 3 *will help you with problem* 7.

1. 5×6.	**5.** 9×3.	**9.** 5×5.	**13.** 0×9.
2. 6×6.	**6.** 4×9.	**10.** 8×10.	**14.** 7×0.
3. 6×7.	**7.** 7×6.	**11.** 9×1.	**15.** 1×0.
4. 8×3.	**8.** 7×10.	**12.** 1×5.	**16.** 3×12.

Note to Teachers.—It will be observed that this book provides only a minimum of drill exercises in the handling of abstract numbers. Whether or not you should give the members of your class additional drill exercises in abstract numbers depends upon the age, academic advancement and the motives of the members of your class. For adult people who have a daily need for the strictly textile mathematics of part II of this book, only such a minimum of drill should be provided as will enable them to *barely* master the handling of abstract numbers, since subsequent matter in the book will provide the incentive and occasion for mastering the handling of abstract numbers.

Where this book is used in the regular day schools of mill communities with children whose motives for study of textile mathematics are not as immediate as those of employed adults, and whose interests lie more in accomplishing the task for the sake of the task, greater provision must be made for the acquirement of automatic number responses.

Multiplication Table

17. Fill out the following table. When filled out you will have a *multiplication table* of all numbers from 1 to 10 to which you can always refer and which you should try to memorize from time to time. The numbers in the top row are to be multiplied by the numbers in the left hand column. The products found in some of the preceding problems are put in their proper places in the table.

	1	2	3	4	5	6	7	8	9	10
1									9	
2										
3								24	27	
4									36	
5					25					
6					30	36	42			
7						42				
8										
9										
10							70	80		

Multiplication Involving Products of Digits Not Exceeding Nine

The easiest way to multiply numbers containing more than one digit is to set the number with the more digits directly above the number with less digits. Suppose we wish to multiply 24 by 2.

$$\begin{array}{r} 24 \\ \underline{2} \end{array}$$

To multiply these numbers, place them one directly under the other, the same as in addition and subtraction.

$$\begin{array}{r} 24 \\ \underline{2} \\ 8 \end{array}$$

Multiplying the units digit of the larger number, 4, by the units digit of the smaller number (4×2), the product is 8. Place the 8 below the line.

$$\begin{array}{r} 24 \\ \underline{2} \\ 48 \end{array}$$

Multiplying the tens digit in the top line by the units digit in the lower line (2×2), the product is 4. Place the 4 below the line.

Therefore, the product of $24 \times 2 = 48$.

EXAMPLE: *What is the product of* 33×3?

$$\begin{array}{r} 33 \\ \underline{3} \\ 99 \end{array}$$

PROBLEMS. *Find the products of the following numbers:*

18. 11 and 2. **20.** 13 and 3. **22.** 14 and 2.

19. 12 and 3. **21.** 23 and 3. **23.** 44 and 2.

Multiplication Involving Products of Digits Exceeding Nine

$$\begin{array}{r} 634 \\ \underline{5} \end{array}$$

Suppose we wish to multiply 634 by 5. Arrange the numbers as before.

$$\begin{array}{r} {\scriptstyle 2} \\ 634 \\ \underline{5} \\ 0 \end{array}$$

Multiply the 4 by the 5. The product is 20. Place the 0 of the 20 below the line directly under the 5. *Carry* the 2 of the 20 directly above the 3.

```
 12
634
  5
---
 70
```

Multiply the 3 by the 5. The product is 15. Add the 2. The sum is 17. Put the 7 of the 17 below the line directly under the 3. *Carry* the 1 of the 17 over the 6.

```
 12
 634
   5
----
3170
```

Multiply the 6 by the 5. The product is 30. Add the 1. The sum is 31. Put the 31 below the line.

Therefore, $634 \times 5 = 3170$.

EXAMPLE: *What is the product of* 752 *and* 8?

```
 41
 752
   8
----
6016
```

PROBLEMS. *Find the products of:*

24. 123×9.
25. 456×7.
26. 841×3.
27. 8×9121.
28. 7×9516.
29. 9×9999.

MULTIPLICATION OF ANY WHOLE NUMBERS

```
  12
 634
 745
----
3170
```

Suppose we wish to multiply 634 by 745. We place one number directly above the other and then we multiply the 634 by the 5 of the 745, just as we did before.

```
  11
  634
  745
 ----
 3170
2536
```

Then we erase the little figures above the top number and multiply by the 4, setting this product down under the 3170, but moved one space to the left.

```
   22
   634
   745
  ----
  3170
 2536
4438
------
472330
```

We again erase the little figures and multiply by the 7, moving the product another space to the left. Then, we add these products.

Therefore, $634 \times 745 = 472{,}330$.

Suppose we wish to multiply 258 by 240.

```
  258
  240
 ----
  000
1032
516
-----
61920
```

But this result is the same as if we merely put one zero under the line and put the 1032 in front of the zero. Hence, we would multiply these numbers as shown at the right.

```
  258
  240
-----
10320
516
-----
61920
```

Suppose we wish to multiply 258 by 204.

```
  258
  204
 ----
 1032
 000
516
-----
52632
```

But this is the same as if we left out the row of zeros. Hence, we multiply as shown at the right.

```
  258
  204
 ----
 1032
516
-----
52632
```

Suppose we wish to multiply 462 by 200.

```
  462
  200
 ----
  000
 000
924
-----
92400
```

But this is the same as:

```
  462
  200
-----
92400
```

EXAMPLE: *A spinning department of a large mill has 508 spinning frames. Each frame has 216 spindles. How many spinning spindles in the department?*

```
   508
   216
  ----
  3048
  508
1016
------
109728
```

Answer: 109,728 spindles.

PROBLEMS:

30. A certain mill averages having 55 cards in active production. The average production of each card per day is 137 pounds. What is the production per week of 55 hours? "7535 lb" day

31. Each yard of lap from a certain picker weighs 15 ounces. What is the weight of a 48-yard lap?

32. What would be the value of 220 bales of cloth at $150 a bale?

33. If one bale of cloth contains 20 pieces of cloth, 25 yards each, how many yards are there in 24 bales?

34. A reed 41 inches long has 24 dents to the inch. How many dents in the reed?

35. How many bobbins are required to fill 1940 batteries, if each battery contains 23 bobbins?

36. The weight of yarn on a full spinning bobbin with 6-inch traverse is about 2 ounces from a $1\frac{3}{4}$-inch ring. How many ounces should a doff weigh from a 320-spindle frame?

37. A buyer sends an order to a mill for 512 bales of cloth, each bale to contain 20 forty-yard pieces. The mill ships him 162 bales. How many yards remain of the order?

38. A mill buys 300 bales of cotton, the average weight being 490 pounds per bale; 14,000 pounds of this cotton go to waste. How many pounds of cloth are produced from this cotton?

39. A mill uses 40 kettles of size a week. Each kettle contains 300 gallons of water, 280 pounds of starch and 44 pounds of sizing tallow. How much of each will be used?

EXAMPLE: *If the slubber clock registers* 13 *hanks per spindle made in a day, how many hanks would be made on* 2 *slubbers of* 88 *spindles?*

If each hank of this size weighs 4 *pounds, how many pounds of roving are produced in a day?*

```
  88            2288
   2               4
 ---            ----
 176            9152 pounds.
  13
 ---
 528
176
----
2288 hanks.
```

40. 200 looms on a certain style of goods weave 52 yards per loom per day; 180 looms on another style weave 48 yards per loom per day. How many yards will the 380 looms weave in six days?

41. In a weave room there are 834 looms. There are 2 harnesses on each loom and each harness contains 890 heddles. How many heddles on all the looms?

42. A cloth woven with 8 harnesses requires 350 heddle eyes to each harness. How many heddle eyes will be required for 275 looms?

43. At 27 cents per side per day, how much would a girl in the spinning room make in 6 days if she runs 10 sides?

44. A man making $3 a day averages working 5 days a week and spends each week $6 for board and $5 for other things. How much will he save in a year?

45. How many dollars will it cost for supplies for 28 sections for a year, if the average cost is $50 a month per section?

46. On the average a tying machine will tie 230 knots in a minute. How many knots will it tie in 55 hours?

47. A drawing-in machine runs 7 hours the first day, 8 hours the second day and 6 hours the third day. How many ends did it draw in the three days, if it draws 144 ends per minute?

CHAPTER V

DIVISION OF WHOLE NUMBERS WITHOUT FINAL REMAINDERS

Division, as its name suggests, is the process of finding how many times one number is contained in another number. Division is denoted by the division sign, ÷, which is read "divided by." Thus, 6 yards ÷ 3 yards is read "six yards divided by three yards." This means "How many 3-yard lengths are contained in a 6-yard length?" We readily see that the answer is 2. Hence, 6 yards ÷ 3 yards = 2. Not 2 yards, but just plain 2.

Now then, what is the meaning of 6 yards ÷ 2? This is read "6 yards divided by 2," and means "How long is each piece when a 6-yard length is divided into 2 equal lengths?" We readily see that the answer is 3 yards. Not plain 3, but 3 yards.

From the above instances we see that division is the reverse of multiplication. Hence, 6 yards ÷ 3 yards also means "What number multiplied by 3 yards = 6 yards?" And hence, 6 yards ÷ 2 means "What number of yards multiplied by 2 = 6 yards?"

PROBLEMS. *What is the meaning of and the answer to the following:*

1. 10 pounds ÷ 5.

2. 12 yards ÷ 3.

3. 15 inches ÷ 5 inches.

4. 16 yards ÷ 2.

5. 16 yards ÷ 2 yards.

6. 8 boxes ÷ 4.

The number divided is called the *dividend*. The number that does the dividing is called the *divisor* and the result is called the *quotient*. Thus, in the expression "6 yards ÷ 3 yards = 2," 6 yards is the dividend, 3 yards is the divisor and 2 is the quotient.

What is the meaning of 6 ÷ 3? This may mean any one of the following:

(*a*) How many parts are contained in 6 when the size of each part is 3? Or:

(*b*) What is the size of each part when 6 contains 3 equal parts? Or:

(*c*) How many times is 3 contained in 6? Or:

(*d*) How many times does 3 go into 6? Or:

(*e*) What number multiplied by 3 equals 6?

Regardless of the meaning, however, the quotient is 2.

PROBLEMS. *Tell which is the dividend, the divisor and the quotient in the following problems, and using the multiplication table, find the quotient:*

7. 42 ÷ 6.

8. 45 ÷ 5.

9. 2 ÷ 1.

10. 2 ÷ 2.

11. 49 bobbins ÷ 7.

12. 49 ÷ 49.

13. 54 ÷ 9.

14. 81 ÷ 9.

15. 100 ÷ 10.

16. 72 shuttles ÷ 8 shuttles.

17. 100 ÷ 100.

18. 100 heddles ÷ 100 heddles.

SHORT DIVISION

The easiest way to divide a number of two or more digits by a number of one digit when we can't find the quotient at a glance, is by *short division*. Suppose we wish to divide 287 by 7. Set them down like this:

$$7\overline{)287}$$

$$\begin{array}{r} 4 \\ 7\overline{)287} \end{array}$$

We see that the divisor, 7, is not contained in 2, the first digit of the dividend. Then we try the first two digits of the dividend. 7 is contained in 28, 4 times. Set the 4 above the line directly over the 8.

$$\begin{array}{r} 41 \\ 7\overline{)287} \end{array}$$

We now see that 7 is contained in 7, 1 time, or once. Set the 1 above the 7 of the dividend and the job is done. Therefore, the quotient of $287 \div 7 = 41$.

$$\begin{array}{r} 41 \\ 7 \\ \hline 287 \end{array}$$

To prove that 41 is the quotient of $287 \div 7$, *multiply* 41 by 7 and the product is 287.

EXAMPLE: *How many times is* 9 *contained in* 81,999?

$$\begin{array}{r} 9111 \\ 9\overline{)81999} \end{array}$$

Answer: 9111 times.

EXAMPLE: *How many times does* 3 *go into* 666?

$$\begin{array}{r} 222 \\ 3\overline{)666} \end{array}$$

PROBLEMS. *Find the quotients of:*

19. $355 \div 5$.

20. $468 \div 2$.

21. $396 \div 3$.

22. $7299 \div 9$.

Suppose we wish to divide 6080 by 8. Set the dividend and divisor down as before.

$$8\overline{)60\,80}$$

$$\begin{array}{r} 7 \\ 8\overline{)60^480} \end{array}$$

$$\begin{array}{r} 7\,6 \\ 8\overline{)60^480} \end{array}$$

$$\begin{array}{r} 7\,60 \\ 8\overline{)60^480} \end{array}$$

8 is not contained in the six. 8 is contained in 60, but not "evenly." What is the nearest number to 60, but smaller than 60, into which 8 goes "evenly"? $8 \times 7 = 56$; $60 - 56 = 4$. So 8 goes into 60, 7 times with a *remainder* of 4. Put the 7 over the 0 of the 60 and "carry" the remainder, 4, in front of the 8 of the dividend. 8 goes into 48, 6 times "evenly." Put the 6 over the 8 of the dividend.

How many times does 8 go into 0? In other words, how many times is something contained in nothing? No times, or zero times, of course. Put the 0 over the 0 of the dividend and we have the answer, 760.

EXAMPLE: *How many times does* 6 *go into* 320,430?

$$\begin{array}{r} 5\ 3\ 4\ 0\ 5 \\ 6\overline{)3\ 2\ {}^{2}0\ {}^{2}4\ 3\ {}^{3}0} \end{array}$$

PROBLEMS. *Find the quotients of:*

23. 7350 ÷ 5. **27.** 1673 pounds ÷ 7.

24. 1442 ÷ 7. **28.** 1728 yards ÷ 6 yards.

25. 1791 ÷ 9. **29.** 720320 ÷ 8.

26. 8040 ÷ 8. **30.** 818271 ÷ 9.

LONG DIVISION

When the divisor contains more than one digit, the easiest way to divide is by *long division.*

$$13\overline{)20865}$$

Suppose we wish to divide 20,865 by 13. We set the divisor and dividend down as before. 13 will not go into 2. It will go into 20, 1 time.

$$\begin{array}{r} 1 \\ 13\overline{)20865} \\ \underline{13} \\ 7 \end{array}$$

Place the 1 over the 0 of the 20. Multiply the 1 by the divisor, 13, and set the product under the 20 of the dividend. Subtract the 13 from the 20. The difference, or remainder, is 7.

$$\begin{array}{r} 16 \\ 13\overline{)20865} \\ \underline{13} \\ 78 \\ \underline{78} \end{array}$$

Bring down the next digit of the dividend, 8, and place it after the remainder, 7. We see that 13 goes into 78, 6 times. Put the 6 over the 8 of the dividend. We multiply the divisor, 13, by the 6, placing the product under the 78 as we do our multiplying. The product is 78. Subtracting 78 from 78, we have no remainder.

$$\begin{array}{r} 160 \\ 13\overline{)20865} \\ \underline{13} \\ 78 \\ \underline{78} \\ 6 \end{array}$$

Bring down the 6. 13 goes into 6, 0 times. Put the 0 over the 6. We could multiply the 13 by 0. The product would be 0. Then we could subtract the 0 and get a remainder of 6. Then we would be no further along than we are now. So bring down the next digit, 5, putting it after the 6.

```
    1605
13)20865
   13
    78
    78
     65
```

We see that 13 goes into 65, 5 times. Put the 5 over the 5 of the dividend and multiply as before, obtaining 65 for a product. Subtracting 65 from 65, there is no remainder. There are no more digits in the dividend. Hence, the division is completed.

$$20{,}865 \div 13 = 1605.$$

EXAMPLE: *Divide* 324,600 *by* 150.

```
        2164
 150)324600
     300
      246
      150
       960
       900
        600
```

PROBLEMS:

31. If 1944 looms are divided equally between 108 weavers, how many looms will be each weaver's share?

32. If a loom will weave 225 yards of cloth in a week, how many weeks will be required for it to weave 9675 yards?

33. A cloth of 48 warp threads per inch contains 1728 warp threads. How wide is the cloth?

34. 840 yards of number one yarn weigh one pound. How many pounds in 74,760 yards?

35. A 60,032 spindle mill is equipped with spinning frames containing 224 spindles to a frame. How many spinning frames are there in the mill?

YARN AND ROVING NUMBERS

The number of yarn is found by dividing 1000 by the number of grains that 120 yards weigh.

EXAMPLE: 120 *yards of a certain size of yarn weigh* 10 *grains. What is the number of the yarn?*

1000 ÷ 10 = 100. The number of the yarn is 100.

36. What is the number of the yarn if 120 yards weigh 20 grains?

37. What is the number of the yarn if 120 yards weigh 25 grains?

38. What is the number of the yarn if 120 yards weigh 40 grains?

39. What is the number of the yarn if 120 yards weigh 50 grains?

The number of roving is found by dividing 100 by the number of grains that 12 yards weigh.

40. What is the number of the roving if 12 yards weigh 10 grains?

41. What is the number of the roving if 12 yards weigh 20 grains?

42. What is the number of the roving if 12 yards weigh 25 grains?

43. What is the number of the roving if 12 yards weigh 50 grains?

44. What is the number of the roving if 12 yards weigh 100 grains?

45. If a certain slubber produces 4576 pounds of a certain size roving in a day, how many days will be required for it to produce 13,728 pounds?

46. If one cotton harness cost $2 and contains 22 biers, how much will 12,100 biers cost? *Hint:* How many times is 22 biers contained in 12,100 biers?

47. 70 spinning frames, 224 spindles to each frame, spin 62,720 pounds in a week. How many pounds does each spindle run?

48. A mill runs 310 days in a year, and manufactures 12,400 bales of cloth averaging 1260 yards per bale. Find the average yards manufactured per day.

49. An order for 300,000 yards of cloth is received. The looms make 156 picks per minute. Each inch of cloth contains 52 picks. How many 10-hour days will be required for 120 looms to fill the order, not allowing for the time that the loom is stopped for fixing, tying-in, etc.?

Hints:

(*a*) How many inches does one loom produce in an hour?

(*b*) How many yards does one loom produce in an hour?

(*c*) How many yards does one loom produce in a day?

(*d*) How many days would one loom require to fill the order?

(*e*) How many days would 120 looms require to fill the order?

50. There are 16 ounces in a pound. A picker lap containing 48 yards weighs 36 pounds. How many ounces does each yard weigh?

Hints:

(*a*) How many ounces does the whole lap weigh?

(*b*) How many ounces does each yard weigh?

51. A picker lap weighs 14 ounces per yard. How many yards should there be in a lap weighing 42 pounds?

Review Problems

Involving Addition, Subtraction, Multiplication and Division

52. A cloth buyer bought 9540 yards of cloth, to be put in 9 bales, each bale to contain the same number of yards. How many yards in each bale?

53. In a certain spinning room, the spinners average 8 sides each. How many spinners will it take to run 424 sides?

54. In one weave room there are 840 looms on 10 alleys; how many looms are there on one alley?

55. At $4 a day, how many days will a man have to work to earn $812?

56. A certain style of cloth is made with 2464 warp ends. 6 beams of 348 ends each are used on the slasher. How many ends are required in the seventh beam to make the required number of ends?

57. Two boxes full of waste weighed as follows: first box, 226 pounds; second box, 196 pounds. How many pounds of waste are there in the two boxes if the empty boxes weigh 111 pounds each?

58. A cloth 36 inches wide is made with 1744 warp ends, allowing 16 extra ends for selvage. How many warp ends per inch are there in the cloth?

59. If a size pump will pump 98 gallons of size in a minute, how long will it require to pump 5880 gallons?

60. If one bobbin of filling weaves 7 inches of cloth, how many bobbins will it take to weave 5908 inches of cloth?

61. On a certain style of cloth one bobbin of filling will weave 11 inches of cloth; how many bobbins will be required to weave 79,244 inches of cloth?

62. 10 slashers run 435,840 yards of warp in 6 days. What is the average production of each slasher per day?

63. A warp is run on a slasher with 9 section beams. The warp contains 3078 ends. How many ends are there on each section beam?

64. A warp containing 2224 ends is to be drawn on 8 harnesses. Each harness is to contain the same number of ends. How many ends on each harness?

65. If a warp is run on a slasher as follows: 6 section beams, 376 ends each; 3 section beams, 348 ends each; one section beam, 324 ends; how many ends should there be in the warp?

66. Drop wires cost $6 per thousand and are put up 5 thousand to the box. How much will 15 boxes cost?

67. If 55 pounds of sizing tallow are used to each kettle of size, how many kettles can be made from 4 barrels containing 440 pounds each?

68. An order for a certain style of cloth is for 100,000 yards, 20 pieces of 50 yards each to the bale. How many bales does the order call for?

69. How many pounds will 100 bales of cloth weigh, each bale containing 20 pieces and each piece containing 30 yards, if 4 yards of the cloth weigh one pound?

70. Find the number of pounds of filling in 60 yards of cloth, if the warp weighs 7 pounds and it takes 5 yards of the cloth to weigh one pound?

71. The front roll on a certain speeder delivers 536 inches of roving in one minute. The flyer makes 1072 turns in one minute. How many twists per inch are being put into the roving?

CHAPTER VI

MULTIPLES, PRIME NUMBERS AND FACTORS

Even Numbers. Any number that can be evenly divided by 2 is an *even number*. Thus, 2, 4, 6, 8, 10 and any number whose right-hand digit is 2, 4, 6, 8 or 0 is an even number because it is divisible by 2.

Odd Numbers. All numbers that are not even numbers are *odd numbers*. Therefore, all numbers whose right-hand digit is 1, 3, 5, 7 or 9 are odd numbers.

Multiples. A product of two or more numbers is a *multiple* of those numbers. $2 \times 3 = 6$. Therefore, 6 is a multiple of 2. Therefore, also, 6 is a multiple of 3. 30 is a multiple of 2. 30 is a multiple of 15. 30 is also a multiple of 3. 30 is also a multiple of 10. 30 is also a multiple of 5 and also of 6. 60 is a multiple of 2.

Prime Numbers. Any number that is not a multiple of other numbers is a *prime number*. In other words, a number that cannot be divided by another number (except itself and 1) is a prime number. Thus, 1, 2, 3, 5, 7, 11, 13, 17 and many other numbers are prime numbers.

Factors. Numbers which multiplied together make another number are *factors* of that number. In other words, a multiple has factors. A prime number has no factors. Thus, 2 and 15; 3 and 10; 5 and 6; and 2, 3 and 5 are *factors* of 30. 2 is *a factor* of 30; 15 is *a factor* of 30; 3 is *a factor* of 30, and so on.

Prime Factors. The prime numbers which multiplied together make another number are *prime factors* of that number. Thus, the prime factors of 30 are 2, 3 and 5.

Multiples of 2. All even numbers, as we have seen, are multiples of 2. That is, 2 is a factor of all even numbers.

Multiples of 3. A number is divisible by 3 if the sum of its digits is divisible by 3. The sum of the digits of 129 = 1 + 2 + 9 = 12. 12 is divisible by 3. Therefore, we shall find that 129 is a multiple of 3.

Multiples of 5. Any number ending in 5 or 0 is a multiple of 5.

The finding of factors and multiples is of very frequent necessity in textile calculations.

Finding the Prime Factors

In factoring we use the division sign made like this: $\underline{)\quad}$ instead of like this: $\overline{)\quad}$.

Example: *Find the prime factors of* 420.

420 is a multiple of 2 because it is an even number.	2)420
210 is a multiple of 2 because it is an even number.	2)210
105 is a multiple of 5 because it ends in 5.	5)105
21 is a multiple of 3 because the sum of its digits is divisible by 3.	3)21
7 is a prime number because it cannot be divided by any other number except itself and 1.	7

Therefore, the prime factors of 420 are 2, 2, 3, 5 and 7.

Proof: $2 \times 2 \times 3 \times 5 \times 7 = 420$.

EXAMPLE: *Find the prime factors of* 6006.

$$\begin{array}{r} 2\underline{)6006} \\ 3\underline{)3003} \\ 7\underline{)1001} \\ 13\underline{)143} \\ 11 \end{array} \qquad \begin{array}{r} 11 \\ 13\overline{)143} \\ \underline{13} \\ 13 \\ 0 \end{array}$$

The prime factors are 2, 3, 7, 13 and 11.

PROBLEMS. *Find the prime factors of:*

1. 120.	**4.** 175.	**7.** 540.	**10.** 1001.
2. 128.	**5.** 210.	**8.** 239.	**11.** 3432.
3. 150.	**6.** 291.	**9.** 840.	**12.** 31416.

Least Common Multiple. The smallest number that is a multiple of two or more numbers is their *least common multiple.* Thus, the least common multiple of 4 and 6 is 12.

FINDING THE LEAST COMMON MULTIPLE

EXAMPLE: *Find the least common multiple of* 24, 30 *and* 36.

We must first find the prime factors of each number.

$$\begin{array}{r} 2\underline{)24} \\ 2\underline{)12} \\ 2\underline{)6} \\ 3 \end{array} \qquad \begin{array}{r} 2\underline{)30} \\ 3\underline{)15} \\ 5 \end{array} \qquad \begin{array}{r} 2\underline{)36} \\ 2\underline{)18} \\ 3\underline{)9} \\ 3 \end{array}$$

The least common multiple since it is to contain 24, 30 and 36 must contain all the prime factors that make up each number. We start with the smallest number, 24. The least common multiple to contain 24 must therefore contain 2, 2, 2 and 3. We set down 2, 2, 2 and 3.

The prime factors of 30 are 2, 3 and 5. Therefore, the least common multiple must contain 2, 3 and 5. But we have already set down a 2 and a 3. Hence, for 30 we set down the 5 only.

The prime factors of 36 are 2, 2, 3 and 3. We have already set down two 2's and one 3. Hence, for 36 we set down one 3.

Hence, the least common multiple $= 2 \times 2 \times 2 \times 3 \times 5 \times 3 = 360$.

Find the least common multiple of the following groups of numbers:

13. 12, 16 and 24.

14. 8, 12 and 24.

15. 5, 9, 10, 15 and 30.

16. 7, 9, 14 and 21.

17. 7, 11 and 13.

18. 24, 36, 48 and 72.

19. 10, 12, 18 and 24.

20. 39, 52 and 91.

21. 36, 144 and 180.

22. 12, 18, 24, 36 and 42.

CHAPTER VII

THE MEANING OF FRACTIONS

UNITS

A. When we are talking about yards, the *unit* is *one yard*. The word *unit* means *one*. In other words, when we are thinking of yards, one means one yard. That is, in all calculations dealing with yards, one yard is the unit. On the other hand, in all calculations dealing with feet, the *unit* is *one foot*. And when we are dealing with inches, the *unit* is *one inch*. So we must always keep clearly in mind the unit with which we are dealing, for we see that the yard unit is 3 times as large as the foot unit and the foot unit is 12 times as large as the inch unit. When we are calculating with yards, the whole number 2 means 2 yards. When we are calculating in inches, the whole number 2 means 2 inches. Now then, when we are calculating in yard units and we wish to express 2 inches, how shall we do it? This brings up the subject of *fractions*.

THE FRACTION AS A PART OR PARTS OF A UNIT

B. Thus far in this book we have learned to add, multiply, divide and subtract whole numbers; that is, whole units. The word *fraction* means a *part* of a unit. A fraction consists of a number directly above another number with a line between. Thus, $\frac{1}{4}$ is a fraction. This fraction is called "one-fourth" or "one-quarter." If we are dealing with inches, $\frac{1}{4}$ means a length that is equal to 1 part when the inch unit is divided into 4 equal parts.

On the ruler shown above, $\frac{1}{4}$ would therefore mean one of the smallest lengths, spaces or distances. That is, $\frac{1}{4}$ would mean the distance between any two adjacent shortest cross lines.

C. The fraction $\frac{2}{4}$, when we are dealing with inches, would mean a length that is equal to 2 parts when the inch unit is divided into 4 equal parts. Hence, on the ruler $\frac{2}{4}$ means any length equal to 2 of the smallest spaces. That is, $\frac{2}{4} = \frac{1}{4} + \frac{1}{4} = 2 \times \frac{1}{4}$.

D. Similarly, $\frac{4}{4}$, when we are dealing with inches, means a length that is equal to 4 parts when the inch unit is divided into 4 equal parts. Hence, on the ruler $\frac{4}{4}$ means any length equal to 4 of the smallest spaces. That is, $\frac{4}{4} = \frac{1}{4} + \frac{1}{4} + \frac{1}{4} + \frac{1}{4} = 4 \times \frac{1}{4}$. But 4 of these spaces = 1 inch. Hence, $\frac{4}{4} = \frac{1}{4} + \frac{1}{4} + \frac{1}{4} + \frac{1}{4} = 4 \times \frac{1}{4} = 1$.

E. Similarly, we see that the fraction $\frac{1}{2}$, when we are dealing with inches, means a length that is equal to 1 part when the inch unit is divided into 2 equal parts. This fraction is called "one-half." Hence, on the ruler $\frac{1}{2}$ means any length that is equal to the distance between one of the longest cross lines and the adjacent next to the longest line. But we also see that this length is equal to two of the smallest spaces. Hence, $\frac{1}{2} = \frac{1}{4} + \frac{1}{4} = \frac{2}{4}$.

F. Similarly, the fraction $\frac{8}{2}$, when we are dealing in inches, means a length equal to 8 parts when the inch

unit is divided into 2 equal parts. Hence, on the ruler $\frac{8}{2}$ means any length equal to 8 of the spaces between any one of the longest cross lines and the adjacent next to longest cross line. Hence, $\frac{8}{2} = \frac{1}{2} + \frac{1}{2} + \frac{1}{2} + \frac{1}{2} + \frac{1}{2} + \frac{1}{2} + \frac{1}{2} + \frac{1}{2} = 8 \times \frac{1}{2}$. But, by counting, we see that 8 of these spaces equals 4 inches. Hence, the fraction $\frac{8}{2} = \frac{1}{2} + \frac{1}{2} + \frac{1}{2} + \frac{1}{2} + \frac{1}{2} + \frac{1}{2} + \frac{1}{2} + \frac{1}{2} = 8 \times \frac{1}{2} = 4$.

Numerator and Denominator. From the preceding discussion, we see that in a fraction the number above the line shows the number of parts of the unit to be considered, while the number below the line shows the total number of parts into which the unit is divided. For this reason, the number above the line is called the *numerator*, which means "*numberer*"; while the number below is called the *denominator*, which means "*namer*," that is, it names the size of the parts, whether they are halves, fourths and so on.

PROBLEMS. *Put your thumb nail on the cross lines of the ruler that show the distances from the left end of the ruler expressed by the following fractions or whole numbers:*

1. $\frac{1}{4}$.	4. $\frac{4}{4}$.	7. $\frac{5}{4}$.	10. $\frac{7}{4}$.	13. 2.	16. $\frac{11}{4}$.
2. $\frac{1}{2}$.	5. $\frac{2}{2}$.	8. $\frac{6}{4}$.	11. $\frac{8}{4}$.	14. $\frac{6}{2}$.	17. $\frac{12}{4}$.
3. $\frac{3}{4}$.	6. 1.	9. $\frac{3}{2}$.	12. $\frac{4}{2}$.	15. 3.	18. $\frac{10}{2}$.

READING OF FRACTIONS

There is a certain method of reading fractions which you will "pick up" from the following:

$\frac{1}{2}$ is read one-half.	$\frac{1}{3}$ is read one-third.
$\frac{2}{2}$ is read two-halves.	$\frac{4}{3}$ is read four-thirds.
$\frac{7}{2}$ is read seven-halves.	$\frac{1}{4}$ is read one-fourth or one-quarter.

$\frac{3}{4}$ is read three-fourths or three-quarters.
$\frac{1}{5}$ is read one-fifth.
$\frac{7}{5}$ is read seven-fifths.
$\frac{1}{6}$ is read one-sixth.
$\frac{5}{6}$ is read five-sixths.
$\frac{1}{7}$ is read one-seventh.
$\frac{1}{10}$ is read one-tenth.
$\frac{1}{20}$ is read one-twentieth.
$\frac{1}{21}$ is read one twenty-first.
$\frac{1}{22}$ is read one twenty-second.
$\frac{31}{31}$ is read thirty-one thirty-firsts.
$\frac{25}{42}$ is read twenty-five forty-seconds.
$\frac{50}{100}$ is read fifty one-hundredths.
$\frac{2}{261}$ is read two two-hundred-sixty-firsts.
$\frac{11}{1000}$ is read eleven one-thousandths.

PROBLEMS. *Read the following fractions:*

19. $\frac{15}{2}$.	**22.** $\frac{44}{4}$.	**25.** $\frac{333}{33}$.	**28.** $\frac{3}{23}$.	**31.** $\frac{21}{109}$.	**34.** $\frac{91}{100}$.
20. $\frac{33}{6}$.	**23.** $\frac{13}{15}$.	**26.** $\frac{33}{13}$.	**29.** $\frac{10}{24}$.	**32.** $\frac{7}{112}$.	**35.** $\frac{101}{1000}$.
21. $\frac{40}{5}$.	**24.** $\frac{7}{8}$.	**27.** $\frac{140}{44}$.	**30.** $\frac{15}{11}$.	**33.** $\frac{55}{545}$.	**36.** $\frac{2}{2000}$.

MEANING OF MIXED NUMBERS

G. A mixed number is a number composed of a whole number and a fraction. Thus, $1\frac{1}{2}$ is a mixed number. It means $1 + \frac{1}{2}$. It is read "one and one-half." If the unit being considered is inches, $1\frac{1}{2}$ means one whole inch plus one-half an inch. On the ruler $1\frac{1}{2}$ inches would mean any distance equal to the distance from the left end of the ruler to the $\frac{1}{2}$-inch cross mark between the 1-inch and 2-inch marks. We see that this distance is also equal to $\frac{1}{2} + \frac{1}{2} + \frac{1}{2}$. Hence, $1\frac{1}{2} = \frac{1}{2} + \frac{1}{2} + \frac{1}{2} = 3 \times \frac{1}{2}$. Similarly, $3\frac{1}{4}$ yards means 3 yards plus $\frac{1}{4}$ of a yard.

PROBLEMS. *Read the following mixed numbers and put your thumb nail on the cross lines of the ruler that show the distances from the left end of the ruler expressed by these mixed numbers:*

37. $1\frac{1}{4}$. **39.** $2\frac{1}{4}$. **41.** $2\frac{1}{2}$. **43.** $4\frac{1}{4}$. **45.** $5\frac{1}{4}$. **47.** $3\frac{3}{4}$.

38. $1\frac{3}{4}$. **40.** $2\frac{3}{4}$. **42.** $5\frac{3}{4}$. **44.** $5\frac{1}{2}$. **46.** $5\frac{3}{4}$. **48.** $3\frac{1}{4}$.

Express the following numbers in the form of digits and fractions; that is, in the form of mixed numbers:

49. Ten and eleven-sixteenths.

50. Two hundred twenty-five and thirty-seven two-hundred-and-firsts.

51. One hundred sixteen and one-hundred-forty-one one-thousandths.

52. Seventeen and two-hundred-twenty-two two-thousandths.

The Fraction as an Indicated Division

H. From paragraph *D* we see that $\frac{4}{4} = 1$. From paragraph *F* we see that $\frac{8}{2} = 4$. From problems 5, 11, 12, 14, 17 and 18 we see that $\frac{2}{2} = 1$; that $\frac{8}{4} = 2$; that $\frac{4}{2} = 2$; that $\frac{6}{2} = 3$; that $\frac{12}{4} = 3$; and that $\frac{10}{2} = 5$. But we see from our study of division if we had divided the numerator of any one of these fractions by the denominator we would have obtained the same result as we did by pointing out the distance on the ruler. That is, $4 \div 4 = 1$; $8 \div 2 = 4$; $2 \div 2 = 1$; $8 \div 4 = 2$; $4 \div 2 = 2$; $6 \div 2 = 3$; $12 \div 4 = 3$; $10 \div 2 = 5$. Hence, we see that a fraction also means that the numerator is to be divided by the denominator. Therefore, $\frac{4}{4}$ means $4 \div 4$; $\frac{8}{2}$ means $8 \div 2$; $\frac{12}{4}$ means $12 \div 4$; $\frac{5}{7}$ means $5 \div 7$; $\frac{9}{11}$ means $9 \div 11$, and so on. Now then, we can divide 4 by 4 and get 1; we can divide 8 by 2 and get 4; but we cannot divide 5 by 7, or 9 by 11 and get anything simpler than $\frac{5}{7}$ or $\frac{9}{11}$. In other words, we cannot *perform* the division, we can only *indicate* it. Hence, we say that a fraction is an *indi-*

cated division. Sometimes in cotton mill calculations, as we shall see later, even though we can *perform* the division and find a simple quotient, it is convenient merely to *indicate* the division by making the dividend and the divisor the numerator and denominator of a fraction.

Indicate the following in fractional form:

53. Fifty-seven divided by sixteen.

54. One thousand six hundred eighty divided by eight hundred forty.

55. The number of pieces when a piece of belting 57 inches long is cut into 16-inch lengths.

56. The length in inches of each piece when 57 inches of belting is cut into 16 pieces.

57. The number of 840-yard lengths contained in 1680 yards.

58. The number of times 120 yards is contained in 840 yards.

59. The number of times 840 yards is contained in 12 yards.

60. The weight of one yard of cloth when 7 yards weigh 1 pound.

Finding the Value. *Finding the value* of an expression means actually performing the operations indicated. Thus, to find the value of 2×2 we actually multiply 2×2 and obtain the product, 4. To find the value of the fraction $\frac{16}{2}$ we actually divide 16 by 2 and obtain the quotient, 8.

Find the value of the following fractions:

61. $\frac{10}{5}$. **63.** $\frac{30}{5}$. **65.** $\frac{1}{2}$. **67.** $\frac{100}{25}$. **69.** $\frac{97}{11}$.

62. $\frac{12}{3}$. **64.** $\frac{42}{7}$. **66.** $\frac{3}{4}$. **68.** $\frac{99}{11}$. **70.** $\frac{1000}{40}$.

The Meaning of a Denominator of 1

1. Since a fraction indicates that the numerator is to be divided by the denominator, the fraction $\frac{2}{1}$ means $2 \div 1$ which, of course, equals 2. Hence, the value of any fraction with a denominator of 1 equals the numerator. Thus, $\frac{30}{1} = 30$. And, therefore, we can make any number into a fraction by making it the numerator of a fraction whose denominator is 1. Thus, $4 = \frac{4}{1}$ or $100 = \frac{100}{1}$.

CHAPTER VIII

REDUCTION OF FRACTIONS, CANCELLATION AND DIVISION WITH FRACTIONAL REMAINDERS

Let us consider the fraction $\frac{12}{6}$. We see at once that the value of $\frac{12}{6}$ is 2. Now let us multiply both the numerator and denominator of $\frac{12}{6}$ by 5. We then have $\dfrac{12 \times 5}{6 \times 5}$ or $\frac{60}{30}$. Dividing 60 by 30 we see that the value of the fraction $\frac{60}{30}$ is 2. Hence, *we can multiply both numerator and denominator of a fraction by the same number without changing its value.* That is,

$$\frac{12}{6} = \frac{5 \times 12}{5 \times 6} = \frac{60}{30}; \text{ or } \frac{1}{2} = \frac{5 \times 1}{5 \times 2} = \frac{5}{10};$$

$$\text{or } \frac{3}{500} = \frac{3 \times 10}{500 \times 10} = \frac{30}{5000}, \text{ and so on.}$$

Let us consider the fraction $\frac{40}{8}$. The value of this fraction is 5. Now let us divide both numerator and denominator of $\frac{40}{8}$ by 4. We then have $\dfrac{40 \div 4}{8 \div 4}$ or $\frac{10}{2}$. The value of the fraction is still 5. Hence, *we can divide both numerator and denominator of a fraction by the same number without changing its value.*

Reducing a fraction to higher terms means *multiplying* the numerator and denominator by the same number. *Reducing a fraction to lower terms* means *dividing* both numerator and denominator by the same common factor. *Reducing a fraction to lowest terms* means dividing both numerator and denominator by their largest common factor. (See chapter VI.)

EXAMPLE: *Reduce $\frac{3}{4}$ to higher terms so that the fraction will have a denominator of* 48.

First, we must find what number multiplied by 4 will give 48.

$$4\overline{)48} \quad 12 \qquad 4 \times 12 = 48. \qquad 3 \times 12 = 36.$$

Therefore, $\frac{3}{4} = \frac{36}{48}$.

EXAMPLE: *Reduce $\frac{5}{71}$ to a fraction with a denominator of* 284.

$$\begin{array}{r} 4 \\ 71\overline{)284} \\ 284 \\ \hline 0 \end{array}$$

Therefore, $\frac{5}{71} = \frac{20}{284}$.

PROBLEMS. *Reducing to higher terms:*

1. Reduce $\frac{1}{25}$ to a fraction with a denominator of 75.
2. Reduce $\frac{3}{4}$ to a fraction with a denominator of 36.
3. Reduce $\frac{7}{8}$ to a fraction with a denominator of 96.
4. Reduce $\frac{5}{4}$ to a fraction with a denominator of 100.
5. Reduce $\frac{7}{20}$ to a fraction with a denominator of 120.

EXAMPLE: *Reduce $\frac{10}{5}$ to lowest terms.*

We see at once that the largest factor common to both numerator and denominator is 5. $10 \div 5 = 2$. $5 \div 5 = 1$. Therefore, $\frac{10}{5} = \frac{2}{1} = 2$.

EXAMPLE: *Reduce $\frac{12}{3}$ to lowest terms.*

$$\frac{12}{3} = 4.$$

EXAMPLE: *Reduce $\frac{6}{8}$ to lowest terms.*

2 is the largest number that will divide both numerator and denominator. Therefore, $\frac{6}{8} = \frac{3}{4}$.

Reduce the following fractions to lowest terms:

6. $\frac{2}{4}$.	9. $\frac{2}{6}$.	12. $\frac{15}{3}$.	15. $\frac{25}{5}$.	18. $\frac{3}{39}$.
7. $\frac{3}{6}$.	10. $\frac{3}{9}$.	13. $\frac{3}{15}$.	16. $\frac{13}{39}$.	19. $\frac{36}{21}$.
8. $\frac{2}{8}$.	11. $\frac{4}{12}$.	14. $\frac{4}{20}$.	17. $\frac{39}{3}$.	20. $\frac{12}{36}$.

In order to reduce fractions with large numerators and denominators to lowest terms when we cannot see their largest common factor at a glance, it is necessary to use longer methods.

EXAMPLE: *Reduce $\frac{240}{504}$ to lowest terms.*

First, find the prime factors of 240 and 504. (See chapter VI.)

$$\begin{array}{r|l}
2 & 240 \\ \hline
2 & 120 \\ \hline
2 & 60 \\ \hline
2 & 30 \\ \hline
3 & 15 \\ \hline
 & 5
\end{array}
\qquad
\begin{array}{r|l}
2 & 504 \\ \hline
2 & 252 \\ \hline
2 & 126 \\ \hline
3 & 63 \\ \hline
3 & 21 \\ \hline
 & 7
\end{array}$$

The common prime factors are three 2's and one 3. Hence, we divide both numerator and denominator by $2 \times 2 \times 2 \times 3$. But instead of dividing, we merely keep the factors that are left in the numerator and denominator after the common factors are removed. Hence, reduced to lowest terms, $\frac{240}{504} = \frac{2 \times 5}{3 \times 7} = \frac{10}{21}$.

Reduce the following fractions to lowest terms:

21. $\frac{21}{189}$. **23.** $\frac{288}{512}$. **25.** $\frac{756}{1140}$.

22. $\frac{250}{550}$. **24.** $\frac{154}{198}$. **26.** $\frac{851}{1219}$.

REDUCTION BY CANCELLATION

This method is called *cancellation* because we *cancel*, or scratch out, the numerator and denominator as we divide.

EXAMPLE: *Reduce $\frac{26}{182}$ to lowest terms.*

$\frac{26}{182}$ We see at a glance that both numerator and denominator are divisible by 2.

$\frac{\overset{13}{\cancel{26}}}{\underset{91}{\cancel{182}}}$ Divide each by 2; cancel out the 26 and 182 and replace them with 13 and 91. We see that the new numerator and denominator are divisible by 13.

$$\frac{\overset{1}{\cancel{13}}\cdot\cancel{26}}{\underset{7}{\cancel{91}}\cdot\cancel{182}}$$

Divide each by 13; cancel out the 13 and 91 and replace them with 1 and 7.

Therefore, $\frac{26}{182} = \frac{1}{7}$.

EXAMPLE: *Reduce $\frac{44}{198}$ to lowest terms.*

$$\frac{\overset{\overset{2}{\cancel{22}}}{\cancel{44}}}{\underset{\underset{9}{\cancel{99}}}{\cancel{198}}} = \frac{2}{9}.$$

Canceling Final 0 Digits. Suppose we wish to reduce $\frac{10}{120}$. Dividing both numerator and denominator by 10, we would have $\frac{1}{12}$. But this has the same effect as if we merely canceled out the 0's.

EXAMPLE: *Reduce $\frac{250}{3600}$.*

$$\frac{25\cancel{0}}{360\cancel{0}} \qquad \text{Answer: } \frac{25}{360} = \frac{5}{72}.$$

EXAMPLE: *Reduce $\frac{2500}{3600}$ to lowest terms.*

$$\frac{25\cancel{0}\cancel{0}}{36\cancel{0}\cancel{0}} \qquad \text{Answer: } \frac{25}{36}.$$

Reduce the following fractions by cancellation to lowest terms:

27. $\frac{1001}{91}$. 29. $\frac{210}{540}$. 31. $\frac{45}{495}$.

28. $\frac{7000}{840}$. 30. $\frac{540}{7000}$. 32. $\frac{840}{31416}$.

REDUCTION OF MIXED NUMBERS TO FRACTIONS

From paragraph *G*, chapter VII, we have seen that $1\frac{1}{2}$ means $\frac{1}{2} + \frac{1}{2} + \frac{1}{2}$. From the definition of a fraction, the numerator shows the number of parts to be considered while the denominator shows the kind of parts.

Hence, $\frac{1}{2} + \frac{1}{2} + \frac{1}{2} = \frac{3}{2}$. Similarly, we can show that $1\frac{1}{4} = 1 + \frac{1}{4} = \frac{4}{4} + \frac{1}{4} = \frac{5}{4}$; and also that $2\frac{3}{4} = 2 + \frac{3}{4} = \frac{8}{4} + \frac{3}{4} = \frac{11}{4}$. These conclusions can easily be verified by counting off spaces on the ruler. Now we see that since $1\frac{1}{2} = \frac{3}{2}$ and $1\frac{1}{4} = \frac{5}{4}$ and $2\frac{3}{4} = \frac{11}{4}$, all we have to do to reduce a mixed number to a fraction is to multiply the whole number by the denominator of the fraction and add the numerator to the product. Thus, in the case of $1\frac{1}{2}$, $1 \times 2 + 1 = 3$; put the 3 over the 2 and we have the answer, $\frac{3}{2}$. In the case of $2\frac{3}{4}$, $2 \times 4 + 3 = 11$; put the 11 over the 4 and we have the answer, $\frac{11}{4}$.

EXAMPLE: *Reduce $5\frac{5}{6}$ to a fraction.*

$5 \times 6 + 5 = 35$. Answer: $\frac{35}{6}$.

Reduce the following mixed numbers to fractions:

33. $2\frac{1}{4}$. **35.** $7\frac{1}{11}$. **37.** $10\frac{6}{7}$. **39.** $25\frac{4}{5}$.

34. $5\frac{3}{4}$. **36.** $9\frac{3}{13}$. **38.** $13\frac{1}{12}$. **40.** $10\frac{3}{100}$.

REDUCTION OF FRACTIONS TO MIXED AND WHOLE NUMBERS

From the definition of a fraction we know that the numerator shows the number of parts to be considered, while the denominator shows the kind of parts. Hence, $\frac{15}{4} = \frac{12}{4} + \frac{3}{4}$. But $\frac{12}{4} = 3$. Therefore, $\frac{15}{4} = 3 + \frac{3}{4}$. From the definition of a mixed number, $3\frac{3}{4}$ means $3 + \frac{3}{4}$. Therefore, $\frac{15}{4} = 3\frac{3}{4}$. This can be verified on the ruler by counting off 15 one-fourth-inch spaces and finding that the distance from the left end of the ruler is 3 inches plus 3 one-fourth-inch spaces. Hence, to reduce a fraction to a mixed number, we divide the denominator into the numerator and keep the remainder as a new numerator. Of course, when there is no remainder, the fraction is reduced to a whole number.

EXAMPLE: *Reduce $\frac{235}{4}$ to a mixed number.*

We see that the numerator and denominator have no common factors. We, then, divide by short division.

$$\begin{array}{r} 5\ 8 \\ 4\overline{)23^35^3} \end{array}$$

We see that after dividing 4 into 35 we have a remainder of 3.

Hence: $\frac{235}{4} = 58\frac{3}{4}$.

EXAMPLE: *Reduce $\frac{3245}{16}$ to a mixed number.*

$$\begin{array}{r} 202 \\ 16\overline{)3245} \\ \underline{32} \\ 45 \\ \underline{32} \\ 13 \end{array}$$

Answer: $202\frac{13}{16}$.

EXAMPLE: *Reduce $\frac{7000}{840}$ to a mixed number.*

We see at a glance that numerator and denominator have common factors.

$$\begin{array}{r} 25 \\ \cancel{1}\cancel{0}\cancel{0} \\ \underline{7\cancel{0}\cancel{0}\cancel{0}} \\ \cancel{8}\cancel{4}\cancel{0} \\ \cancel{1}\cancel{2} \\ 3 \end{array} \qquad \begin{array}{r} 8 \\ 3\overline{)25^1} \end{array}$$

Answer: $8\frac{1}{3}$.

EXAMPLE: *Reduce $\frac{1358}{14}$.*

$$\begin{array}{r} 97 \\ \cancel{6}7\cancel{9} \\ \underline{\cancel{1}\cancel{3}5\cancel{8}} \\ \cancel{1}\cancel{4} \\ \cancel{7} \end{array}$$

Answer: 97.

Reduce the following fractions to mixed or whole numbers:

41. $\frac{6}{2}$.	**44.** $\frac{7}{4}$.	**47.** $\frac{147}{16}$.	**50.** $\frac{6400}{720}$.
42. $\frac{9}{3}$.	**45.** $\frac{10}{3}$.	**48.** $\frac{200}{40}$.	**51.** $\frac{70000}{31416}$.
43. $\frac{20}{5}$.	**46.** $\frac{19}{5}$.	**49.** $\frac{694}{7}$.	**52.** $\frac{38750}{2500}$.

Long and Short Division with Fractional Remainders

In chapter V we learned how to divide numbers when there is no final remainder. We are now prepared to divide numbers with fractional remainders.

Example: *Divide* 88 *by* 5.

$$\begin{array}{r} 1\,7\frac{3}{5} \\ 5\overline{)8^{3}8^{3}} \end{array} \qquad \text{Answer: } 17\tfrac{3}{5}.$$

Example: *Divide* 1255 *by* 27.

$$\begin{array}{rl} 46\frac{13}{27} & \\ 27\overline{)\,1255} & \\ 108 & \\ \hline 175 & \qquad \text{Answer: } 46\tfrac{13}{27}. \\ 162 & \\ \hline 13 & \text{Remainder.} \end{array}$$

53. What is the number of the yarn if 120 yards weigh 60 grains?

54. What is the number of the yarn if 120 yards weigh 75 grains?

55. What is the number of the roving if 12 yards weigh 13 grains?

56. A reed 42 inches long contains 945 dents. How many dents are there to the inch?

57. A picker lap containing 50 yards weighs 45 pounds. How many ounces does each yard weigh?

58. 6 yards of card sliver weigh 351 grains. What is the weight of the card sliver per yard?

CHAPTER IX

ADDITION AND SUBTRACTION OF FRACTIONS AND MIXED NUMBERS

Addition of Fractions

From the definition of fractions we have seen that the numerator shows the number of parts to be considered and the denominator shows the kinds of parts. Hence, if we wish to add two or more fractions all of which have the same denominator, we merely add their numerators. Thus, $\frac{1}{4} + \frac{2}{4} = \frac{3}{4}$; $\frac{1}{2} + \frac{3}{2} + \frac{2}{2} = \frac{6}{2} = 2$. These conclusions can easily be verified by counting off these spaces on the ruler. This is just as simple as adding 1 bobbin and 2 bobbins and getting 3 bobbins for an answer.

Problems. *Add the following fractions and reduce your answers to lowest terms. If the numerator is larger than the denominator, reduce your answer to a mixed or whole number. Check your answers by counting spaces on a ruler:*

1. $\frac{1}{4} + \frac{3}{4}$. **3.** $\frac{2}{4} + \frac{7}{4} + \frac{1}{4}$. **5.** $\frac{3}{4} + \frac{5}{4} + \frac{1}{4} + \frac{3}{4}$.

2. $\frac{2}{4} + \frac{5}{4}$. **4.** $\frac{1}{2} + \frac{7}{2} + \frac{3}{2}$. **6.** $\frac{2}{4} + \frac{3}{4} + \frac{5}{4} + \frac{7}{4}$.

Least Common Denominator. Fractions to be added must have the same denominator; that is, a *common denominator.* Fractions not having the same denominator, must be reduced to a common denominator; and in order to save work should be reduced to their *least common denominator.*

EXAMPLE: *Add* $\frac{6}{4} + \frac{1}{2}$.

We see at once that $\frac{6}{4} = \frac{3}{2}$. Therefore, $\frac{6}{4} + \frac{1}{2} = \frac{3}{2} + \frac{1}{2} = \frac{4}{2} = 2$. Answer: 2.

EXAMPLE: *Add* $\frac{3}{10} + \frac{1}{5}$.

We see at once that $\frac{1}{5} = \frac{2}{10}$. Therefore, $\frac{3}{10} + \frac{1}{5} = \frac{3}{10} + \frac{2}{10} = \frac{5}{10} = \frac{1}{2}$. Answer: $\frac{1}{2}$.

EXAMPLE: *Add* $2\frac{4}{9} + \frac{2}{3}$.

$2\frac{4}{9} + \frac{2}{3} = 2\frac{4}{9} + \frac{6}{9} = 2\frac{10}{9} = 2 + \frac{10}{9} = 2 + 1\frac{1}{9} = 3\frac{1}{9}$. Answer: $3\frac{1}{9}$.

In the two preceding examples, the common denominator to which the fractions were reduced was also the least common multiple of the separate denominators. When we cannot at once see the least common multiple of the separate denominators, we must find it by the usual process as shown in chapter VI.

EXAMPLE: *Add* $\frac{5}{24} + \frac{7}{30} + \frac{1}{48}$.

$$\begin{array}{lll} 2\underline{)24} & 2\underline{)30} & 2\underline{)48} \\ 2\underline{)12} & 3\underline{)15} & 2\underline{)24} \\ \;\;2\underline{)6} & \;\;\;\;5 & 2\underline{)12} \\ \;\;\;\;3 & & \;\;2\underline{)6} \\ & & \;\;\;\;3 \end{array}$$

Least common denominator $= 2 \times 2 \times 2 \times 3 \times 5 \times 2 = 240$. $\frac{5}{24}$ reduced to a fraction with a denominator of 240 gives us $\frac{50}{240}$. $\frac{7}{30}$ reduced to a fraction with a denominator of 240 gives us $\frac{56}{240}$. $\frac{1}{48}$ reduced to a fraction with a denominator of 240 gives us $\frac{5}{240}$. Adding the numerators $(50 + 56 + 5)$, we obtain the new numerator 111. Hence, $\frac{5}{24} + \frac{7}{30} + \frac{1}{48} = \frac{111}{240}$. Reducing $\frac{111}{240}$, we obtain $\frac{37}{80}$. Answer: $\frac{37}{80}$.

PROBLEMS. *Add the following by the method most suitable to each problem:*

7. $3\frac{1}{6}+\frac{3}{6}+\frac{8}{12}$.	**10.** $11\frac{1}{4}+14\frac{1}{8}+1\frac{1}{5}$.	**13.** $\frac{3}{28}+\frac{4}{30}+\frac{5}{36}$.
8. $2\frac{3}{8}+\frac{5}{16}+\frac{1}{24}$.	**11.** $\frac{3}{40}+\frac{1}{16}+\frac{3}{32}$.	**14.** $\frac{3}{40}+\frac{6}{35}+\frac{3}{25}$.
9. $\frac{5}{22}+\frac{3}{11}+\frac{9}{99}$.	**12.** $\frac{1}{24}+\frac{3}{28}+\frac{4}{36}$.	**15.** $10\frac{1}{13}+3\frac{1}{5}+8\frac{1}{12}$.

A convenient way of adding mixed numbers is to set them down in a column as in ordinary addition.

EXAMPLE: *Add* $13\frac{1}{4}$, $22\frac{1}{2}$, $45\frac{1}{3}$ *and* $64\frac{2}{3}$.

$$\begin{array}{rl} 13\frac{1}{4} & 3 \\ 22\frac{1}{2} & 6 \\ 45\frac{1}{3} & 4 \\ 64\frac{2}{3} & 8 \\ \hline 144 & \frac{21}{12} = 1\frac{9}{12} \\ 1\frac{9}{12} & \\ \hline 145\frac{9}{12} & \end{array}$$

Add the whole numbers.

Find the common denominator of the fractions. We see that the common denominator is 12. Convert the fractions to 12ths and put the new numerators in a column at the right. Add the numerators, put the sum over the common denominator and reduce to a mixed number. Add the mixed number to the sum of the whole numbers. This sum is the answer.

Answer: $145\frac{9}{12}$.

16. Section No. 1 made $3\frac{1}{4}$ pounds of filling waste in one day; section No. 2 made $3\frac{3}{4}$ pounds; section No. 3 made 4 pounds; and section No. 4 made $2\frac{1}{2}$ pounds. How many pounds of waste did the four sections make?

17. What would be the total weight of 4 rolls of cloth weighing as follows: the first, $10\frac{1}{4}$ pounds; the second, $9\frac{1}{4}$ pounds; the third, $12\frac{3}{4}$; and the fourth, $14\frac{1}{2}$ pounds?

18. Four balls of waste weighed as follows: first ball, $12\frac{1}{2}$ pounds; second ball, $13\frac{3}{4}$; third ball, $9\frac{1}{4}$ pounds; and the fourth ball, $10\frac{1}{2}$ pounds. What was the total weight of the four balls?

19. The friction on a slasher was run too tight and made 4 bad warps with waste as follows: first beam, $10\frac{3}{4}$ pounds; second beam, $9\frac{1}{4}$ pounds; third beam, $12\frac{1}{2}$ pounds; and fourth beam, $13\frac{1}{2}$ pounds. What was the total waste?

20. A fixer worked as follows: Monday, 10 hours; Tuesday, $9\frac{1}{2}$ hours; Wednesday, $10\frac{3}{4}$ hours; Thursday, $10\frac{1}{2}$ hours; Friday, $9\frac{1}{2}$ hours; Saturday, $5\frac{1}{4}$ hours. How many hours did he put in during the week?

SUBTRACTION OF FRACTIONS

EXAMPLE: *Find the difference between* $\frac{5}{4}$ *and* $\frac{2}{4}$.

$\frac{5}{4} - \frac{2}{4} = \frac{3}{4}$. Answer: $\frac{3}{4}$.

EXAMPLE: *Find the difference between* $\frac{4}{16}$ *and* $\frac{3}{8}$.

$\frac{4}{16} = \frac{2}{8}$. $\frac{3}{8} - \frac{2}{8} = \frac{1}{8}$. Answer: $\frac{1}{8}$.

EXAMPLE: *Subtract* $\frac{1}{5}$ *from* $\frac{3}{10}$.

$\frac{1}{5} = \frac{2}{10}$. $\frac{3}{10} - \frac{2}{10} = \frac{1}{10}$. Answer: $\frac{1}{10}$.

EXAMPLE: *Subtract* $\frac{2}{9}$ *from* $2\frac{3}{9}$.

$2\frac{3}{9} - \frac{2}{9} = 2\frac{1}{9}$. Answer: $2\frac{1}{9}$.

EXAMPLE: *What is the difference between* $\frac{2}{3}$ *and* $2\frac{4}{9}$?

$2\frac{4}{9} - \frac{2}{3} = \frac{22}{9} - \frac{6}{9} = \frac{16}{9} = 1\frac{7}{9}$. Answer: $1\frac{7}{9}$.

EXAMPLE: *Find the difference between* $8\frac{25}{30}$ *and* $5\frac{7}{36}$.

$$\begin{array}{r|l} 2 & 30 \\ 3 & 15 \\ & 5 \end{array} \qquad \begin{array}{r|l} 2 & 36 \\ 2 & 18 \\ 3 & 9 \\ & 3 \end{array}$$

Least common denominator is $2 \times 3 \times 5 \times 2 \times 3 = 180$.

$$\begin{array}{r} 8\frac{25}{30} \\ -5\frac{7}{36} \\ \hline 3 \\ +\frac{23}{36} \\ \hline 3\frac{23}{36} \end{array} \qquad \begin{array}{r} 150 \\ -\ 35 \\ \hline \frac{115}{180} = \frac{23}{36} \end{array}$$

Answer: $3\frac{23}{36}$.

Subtract the whole numbers. Convert the fractions to 180ths and put the new numerators in a column to the right. Subtract the new numerators, put the difference over the common denominator and reduce. Add the difference of the fractions to the difference of the numerators.

EXAMPLE: *Find the difference between* $8\frac{25}{30}$ *and* $5\frac{35}{36}$.

Least common denominator is 180.

$$\begin{array}{r} 7\phantom{\frac{25}{30}} \\ \cancel{8}\frac{25}{30} \\ -5\frac{35}{36} \\ \hline 2 \\ +\frac{31}{36} \\ \hline 2\frac{31}{36} \end{array} \qquad \begin{array}{r} 180 \\ \underline{150} \\ 330 \\ -175 \\ \hline \frac{155}{180} = \frac{31}{36} \end{array}$$

Answer: $2\frac{31}{36}$.

Explanation: $8\frac{25}{30} = 8\frac{150}{180} = 8 + \frac{150}{180} = 7 + 1 + \frac{150}{180} = 7 + \frac{180}{180} + \frac{150}{180} = 7\frac{330}{180}$.

Proceed as in the previous example.

Find the difference between the following numbers by the method most suitable to each problem. Do as much of the work in your head as possible.

21. $\frac{3}{2}$ and $\frac{9}{2}$.	**25.** $5\frac{3}{16}$ and $7\frac{1}{8}$.	**29.** $21\frac{13}{95}$ and $\frac{4}{19}$.
22. $\frac{7}{8}$ and $\frac{3}{8}$.	**26.** $10\frac{1}{8}$ and $9\frac{7}{8}$.	**30.** $10\frac{23}{36}$ and $29\frac{11}{30}$.
23. $1\frac{1}{8}$ and $1\frac{5}{8}$.	**27.** $12\frac{15}{16}$ and $12\frac{3}{8}$.	**31.** 32 and $26\frac{19}{31}$.
24. $3\frac{3}{16}$ and $4\frac{1}{16}$.	**28.** $13\frac{6}{7}$ and $21\frac{1}{3}$.	**32.** $101\frac{1}{18}$ and $93\frac{5}{6}$.

33. A certain warper beam when full weighs $517\frac{1}{4}$ pounds. The empty beam weighs $98\frac{3}{4}$ pounds. What is the weight of the yarn on the beam?

34. The weight of warp in a cut of cloth is $9\frac{3}{4}$ pounds. If the weight of the cut is $15\frac{1}{2}$ pounds, what is the weight of the filling?

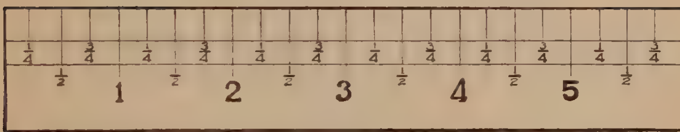
35. The width of the finished cloth on a certain loom is $34\frac{1}{2}$ inches. The width of the warp in the reed is $36\frac{1}{16}$ inches. How much does the cloth contract in width during weaving?

36. A certain cut of warp as it came from the slasher was $63\frac{1}{12}$ yards long. The cloth woven from this warp measured $59\frac{1}{2}$ yards long. How much did the warp contract during weaving?

37. A certain full slubber bobbin weighs $50\frac{1}{4}$ ounces. The empty bobbin weighs $6\frac{1}{2}$ ounces. What is the weight of slubber roving on the bobbin?

CHAPTER X

MULTIPLICATION OF FRACTIONS



Multiplication of Fractions and Whole Numbers. Multiplication always means adding a number to itself a certain number of times. Hence, $4 \times \frac{1}{2}$ must mean $\frac{1}{2} + \frac{1}{2} + \frac{1}{2} + \frac{1}{2}$. From what we have learned of addition of fractions, $\frac{1}{2} + \frac{1}{2} + \frac{1}{2} + \frac{1}{2} = \frac{4}{2}$. Therefore, $4 \times \frac{1}{2} = \frac{4}{2} = \frac{4 \times 1}{2} = 2$. By counting off 4 $\frac{1}{2}$-inch spaces on the above ruler, we arrive at the 2-inch mark. Similarly, $4 \times \frac{3}{4}$ means $\frac{3}{4} + \frac{3}{4} + \frac{3}{4} + \frac{3}{4} = \frac{12}{4} = \frac{4 \times 3}{4} = 3$. We can verify this also by counting off $\frac{3}{4}$-inch spaces on the ruler. Hence, *to multiply a fraction by a whole number we multiply the numerator by the whole number and place the product over the denominator.*

Meaning of the Word "Of" after a Fraction. When we say "a fourth of 4 inches," we really mean the length of one of the parts when 4 inches are divided into 4 equal parts, which, of course, is a 1-inch length. When we say "three quarters of 4 inches," we really mean 3 times one of these 1-inch lengths, which, of course, is a 3-inch length. That is, $\frac{1}{4}$ of $4 = 1$; $\frac{3}{4}$ of $4 = 3$. But from the preceding paragraph $\frac{1}{4} \times 4 = 1$ and

$\frac{3}{4} \times 4 = 3$. Hence, $\frac{1}{4}$ of $4 = \frac{1}{4} \times 4$ and $\frac{3}{4}$ of $4 = \frac{3}{4} \times 4$. Therefore, "of" between a fraction and another number means to multiply the number and the fraction together.

Multiplication of a Fraction by a Fraction. When we say "$\frac{1}{2}$ of $\frac{3}{2}$ of an inch" we really mean the length of one of the parts when $\frac{3}{2}$ of an inch is divided into 2 equal parts. Looking at the ruler we see that this is $\frac{3}{4}$ of an inch. From the preceding paragraph we see that $\frac{1}{2}$ of $\frac{3}{2} = \frac{1}{2} \times \frac{3}{2}$. Therefore, $\frac{1}{2} \times \frac{3}{2} = \frac{3}{4} = \dfrac{1 \times 3}{2 \times 2}$. Hence, *to multiply one fraction by another, we multiply the numerators together and the denominators together.*

EXAMPLE: *Multiply* 4 *by* $\frac{3}{5}$.

$$4 \times \frac{3}{5} = \frac{4 \times 3}{5} = \frac{12}{5} = 2\frac{2}{5}.$$

EXAMPLE: *Multiply* $\frac{4}{5}$ *by* $\frac{3}{5}$.

$$\frac{4}{5} \times \frac{3}{5} = \frac{4 \times 3}{5 \times 5} = \frac{12}{25}.$$

PROBLEMS. *Perform the following multiplications, reducing and checking your answers on the ruler:*

1. $5 \times \frac{1}{2}$.
2. $6 \times \frac{1}{2}$.
3. $7 \times \frac{1}{4}$.
4. $\frac{1}{2} \times 7$.
5. $10 \times \frac{1}{4}$.
6. $\frac{1}{2} \times 10$.
7. $\frac{1}{2} \times \frac{2}{2}$.
8. $\frac{1}{2} \times 1$.
9. $\frac{5}{2} \times \frac{1}{2}$.
10. $\frac{3}{2} \times \frac{5}{2}$.
11. $\frac{4}{2} \times \frac{3}{2}$.
12. $\frac{4}{2} \times \frac{5}{2}$.

Cancellation. Suppose we wish to multiply $\frac{6}{5}$ by $\frac{10}{9}$.

$$\frac{6}{5} \times \frac{10}{9} = \frac{6 \times 10}{5 \times 9} = \frac{60}{45} = 1\frac{1}{3}.$$

Instead of multiplying and then reducing, let us reduce first, $\frac{6}{5} \times \frac{10}{9} = \dfrac{6 \times 10}{5 \times 9}$. We see that we can divide both numerator and denominator of this fraction by 3 and by 5, as follows:

$$\frac{\overset{2}{\cancel{6}} \times \overset{2}{\cancel{10}}}{\underset{1}{\cancel{5}} \times \underset{3}{\cancel{9}}} = \frac{2 \times 2}{1 \times 3} = \frac{4}{3} = 1\frac{1}{3}.$$

5 divides into 5, 1 time. It is not necessary, however, to put down the 1. We now see that we could have canceled when our problem was in the form of $\frac{6}{5} \times \frac{10}{9}$ as follows:

$$\frac{\overset{2}{\cancel{6}}}{\cancel{5}} \times \frac{\overset{2}{\cancel{10}}}{\underset{3}{\cancel{9}}} = \frac{4}{3} = 1\frac{1}{3}.$$

EXAMPLE: *Multiply* $4 \times \frac{3}{4} \times \frac{5}{6} \times \frac{3}{5}$.

$$\cancel{4} \times \frac{\cancel{3}}{\cancel{4}} \times \frac{\cancel{5}}{\underset{2}{\cancel{6}}} \times \frac{3}{\cancel{5}} = \frac{3}{2} = 1\frac{1}{2}.$$

Perform the following multiplication, using cancellation:

13. $\frac{10}{13} \times \frac{25}{3} \times \frac{13}{30} \times 12$.

14. $\frac{1}{26} \times \frac{39}{70} \times \frac{35}{42} \times 10$.

15. $\frac{2}{3} \times \frac{7}{5} \times 30 \times \frac{10}{21}$.

16. $840 \times \frac{4}{7000} \times \frac{60}{16}$.

MULTIPLICATION OF MIXED NUMBERS

Multiplication of a Whole Number and a Mixed Number. Suppose we wish to multiply $142\frac{3}{8}$ by 117. $142\frac{3}{8} \times 117 = \frac{1139}{8} \times 117 = \frac{133263}{8} = 16657\frac{7}{8}$.

$$\begin{array}{r} 142\frac{3}{8} \\ \underline{117} \\ 994 \\ 142 \\ 142 \\ \underline{43\frac{7}{8}} \\ 16657\frac{7}{8} \end{array} \qquad \begin{array}{r} 117 \\ \underline{3} \\ 8\overline{)351} \\ 43\frac{7}{8} \end{array}$$

We can also do this problem as shown to the left. Set the numbers down in the usual manner for multiplication. Multiply the whole part of the mixed number and the whole number. Then find the value of $\frac{3}{8} \times 117$. Then add. This is usually an easier method when the mixed number is large.

Suppose we wish to multiply 239 by $112\frac{2}{3}$.

$$239 \times 112\frac{2}{3} = 239 \times \frac{338}{3} = 26927\frac{1}{3}.$$

$$\begin{array}{r} 239 \\ \underline{112\frac{2}{3}} \\ 478 \\ 239 \\ 239 \\ \underline{159\frac{1}{3}} \\ 26927\frac{1}{3} \end{array} \qquad \begin{array}{r} 239 \\ \underline{2} \\ 3\overline{)478} \\ 159\frac{1}{3} \end{array}$$

We can also do this problem by setting the numbers down in the usual manner for multiplication. This method is usually the easier method when the mixed number is large.

Multiplication of Mixed Numbers by Fractions and Mixed Numbers. Suppose we wish to multiply $14\frac{1}{2}$ by $\frac{1}{2}$. $14\frac{1}{2} \times \frac{1}{2} = \frac{29}{2} \times \frac{1}{2} = \frac{29}{4} = 7\frac{1}{4}$.

Suppose we wish to multiply $239\frac{1}{2}$ by $12\frac{2}{3}$.

$$239\frac{1}{2} \times 12\frac{2}{3} = \frac{478}{\cancel{2}} \times \frac{\overset{19}{\cancel{38}}}{3} = 9082.$$

We could set this problem down in the usual manner for multiplication and perform the work. But it is not practical to do so.

Multiply the following numbers by the more suitable method:

17. $1\frac{1}{2} \times 3$.	**19.** $240 \times 12\frac{3}{5}$.	**21.** $1\frac{1}{2} \times 4\frac{1}{2}$.
18. $3\frac{3}{4} \times 7$.	**20.** $477 \times 24\frac{2}{3}$.	**22.** $15\frac{2}{3} \times 14\frac{3}{8}$.

EXAMPLE: *There are* 16 *ounces in a pound. How many ounces in three-quarters of a pound?*

$\frac{3}{\cancel{4}} \times \overset{4}{\cancel{16}} = 12.$ Answer: 12 ounces in $\frac{3}{4}$ of a pound.

PROBLEMS:

23. (*a*) How many ounces in seven-eighths of a pound?

(*b*) How many ounces in eleven-sixteenths of a pound?

24. There are 36 inches in a yard.

(*a*) How many inches in two-thirds of a yard?

(*b*) How many inches in three-quarters of a yard?

25. There are 7000 grains in a pound. How many grains in four-sevenths of a pound?

26. There are 60 minutes in one hour.
(*a*) How many minutes in three-quarters of an hour?
(*b*) How many minutes in two-thirds of an hour?

27. How many yards of cloth will 420 looms weave in 55 hours if one loom weaves $4\frac{1}{4}$ yards per hour?

28. The knock-off motion on a picker is set to make lap rolls containing 52 yards of lap. If the lap weighs $13\frac{3}{4}$ ounces per yard, how many pounds and ounces should the full lap roll weigh?

29. If a lap roll containing 48 yards of what is supposed to be $14\frac{1}{2}$-ounce lap (that is, $14\frac{1}{2}$ ounces per yard) weighs $42\frac{3}{4}$ pounds, how many pounds is it short of what it is supposed to weigh?

30. If a reed has $22\frac{1}{4}$ dents in one inch, how many dents in 40 inches?

31. If on one loom there are $2\frac{1}{2}$ pounds of strapping, how many pounds on 800 looms?

32. If it costs $15\frac{3}{4}$ cents to manufacture one yard of cloth, what will it cost to manufacture 12 yards?

33. How many ends would there be in the warp of a certain kind of cloth if the cloth is $34\frac{3}{4}$ inches wide and has 64 warp ends per inch?

34. A certain card produces $146\frac{3}{4}$ pounds of a certain sliver per day. How much will it produce in $5\frac{1}{2}$ days?

35. The front roll of a slubber is delivering $596\frac{8}{10}$ inches of roving per minute and the spindle puts $1\frac{1}{2}$

twists per inch in the roving; how many turns is the spindle making in a minute?

NOTE: Each turn of the spindle puts one turn in the roving.

36. A weaver earned \$28 in a week and another weaver earned $\frac{6}{7}$ as much. What did the last weaver earn?

37. A certain cloth weighs one-seventh of a pound per yard. What should be the weight of a $58\frac{1}{2}$-yard cut?

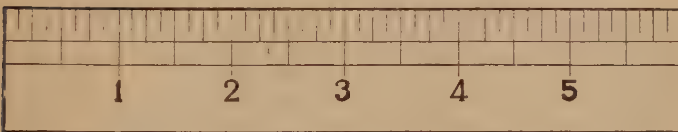
38. A mill receives the following castings from the foundry: 27 gear blanks, $3\frac{1}{8}$ pounds each; 42 treadle rolls, $\frac{1}{2}$ pound each; 90 treadles, $4\frac{1}{16}$ pounds each. Find the number of pounds of casting received.

39. An alloy used for machine bearings is $\frac{24}{29}$ copper, $\frac{4}{29}$ tin and $\frac{1}{29}$ zinc. How many pounds of each in 261 pounds of alloy?

40. One kind of sizing compound is $\frac{7}{20}$ water, $\frac{3}{10}$ tallow, $\frac{1}{10}$ starch, $\frac{1}{5}$ crude glycerine and $\frac{1}{20}$ ash. How many pounds of each will be needed to make 440 pounds of sizing compound?

CHAPTER XI

DIVISION OF FRACTIONS AND REDUCTION OF COMPLEX FRACTIONS



Division of Fractions and Mixed Numbers by a Whole Number. We have seen that $\frac{3}{4}$ means the same thing as $3 \times \frac{1}{4}$. Therefore, $\frac{3}{4}$ divided by $3 = \frac{1}{4}$ just like 3 yards divided by 3 means 1 yard. By taking the first $\frac{3}{4}$ of an inch on the ruler and then taking one of the 3 equal parts into which it is divided, we see we have $\frac{1}{4}$ of an inch. Hence, $\frac{3}{4} \div 3 = \frac{1}{4}$. Similarly, $2\frac{1}{2} \div 5 = \frac{5}{2} \div 5 = \frac{1}{2}$.

PROBLEMS. *Find the value of the following expressions and check your answers on the ruler:*

1. $\frac{6}{8} \div 2$.	**3.** $\frac{7}{8} \div 7$.	**5.** $\frac{12}{8} \div 4$.	**7.** $2\frac{1}{4} \div 3$.
2. $\frac{6}{8} \div 3$.	**4.** $\frac{5}{8} \div 5$.	**6.** $1\frac{1}{8} \div 3$.	**8.** $4\frac{3}{8} \div 7$.

Complex Fractions as Indicated Divisions. There is another way of setting down the above problems. We have learned that a fraction is also an indicated division. Hence, we can indicate the division of a fraction by a whole number by making the fraction the numerator and the whole number the denominator.

Thus, we can put down $\frac{3}{4} \div 3$ in this manner: $\dfrac{\frac{3}{4}}{3}$. This is one kind of a *complex fraction* or *complicated fraction.* In our textile calculations we shall have all kinds of complex fractions. We have seen that $\frac{3}{4} \div 3 = \frac{1}{4}$. Therefore, $\dfrac{\frac{3}{4}}{3} = \frac{1}{4}$. Similarly, $\dfrac{1\frac{1}{8}}{3} = \dfrac{\frac{9}{8}}{3} = \frac{3}{8}$.

Find the value of the following expressions, checking your results on the ruler:

9. $\dfrac{\frac{10}{8}}{2}$.	12. $\dfrac{1\frac{1}{4}}{5}$.	15. $\dfrac{3\frac{3}{4}}{5}$.	18. $\dfrac{2\frac{5}{8}}{3}$.
10. $\dfrac{\frac{12}{4}}{4}$.	13. $\dfrac{3\frac{1}{4}}{13}$.	16. $\dfrac{6\frac{3}{4}}{3}$.	19. $\dfrac{2\frac{5}{8}}{7}$.
11. $\dfrac{\frac{12}{4}}{3}$.	14. $\dfrac{3\frac{3}{4}}{3}$.	17. $\dfrac{6\frac{3}{4}}{9}$.	20. $\dfrac{3\frac{1}{8}}{5}$.

There is another way of dividing a fraction by a whole number. $\frac{3}{4} \div 3 = \frac{1}{4}$. We could have gotten the same result by multiplying the denominator of the fraction by the whole number. Thus, $\frac{3}{4} \div 3 = \dfrac{3}{4 \times 3} = \frac{3}{12} = \frac{1}{4}$. That is to say, *multiplying the denominator has the same effect as dividing the numerator.* Putting the problem in the form of a complex fraction,

$$\frac{\frac{3}{4}}{3} = \frac{3}{3 \times 4} = \frac{1}{4}.$$

Multiplying the denominator is the only way we can divide a fraction by a whole number when the numerator of the fraction is not divisible by the whole number. For instance,

$$\frac{\frac{1}{2}}{4} = \frac{1}{4 \times 2} = \frac{1}{8}.$$

We can verify this on the rule by taking one of the parts resulting from dividing $\frac{1}{2}$ an inch into 4 equal parts and finding that it is $\frac{1}{8}$ of an inch.

Find the value of the following expressions:

21. $\frac{1}{2} \div 2.$ **24.** $\frac{\frac{5}{8}}{3}.$ **27.** $\frac{2\frac{5}{9}}{3}.$

22. $\frac{3}{4} \div 2.$ **25.** $\frac{\frac{7}{16}}{5}.$ **28.** $9\frac{7}{10} \div 24.$

23. $\frac{\frac{5}{8}}{2}.$ **26.** $1\frac{1}{8} \div 2.$ **29.** $\frac{45\frac{17}{100}}{22}.$

Oftentimes we can divide some mixed numbers without reducing them to fractions. What is the value of $4\frac{1}{2} \div 2$? Since $4\frac{1}{2} = 4 + \frac{1}{2}$, we see at once that $4\frac{1}{2} \div 2 = 2 + \frac{1}{2 \times 2} = 2\frac{1}{4}$. Similarly, $3\frac{3}{8} \div 3 = 1\frac{1}{8}$.

Find the value of the following without putting any work on paper:

30. $2\frac{1}{2} \div 2.$ **32.** $3\frac{3}{4} \div 3.$ **34.** $\frac{15\frac{3}{7}}{3}.$ **36.** $\frac{100\frac{1}{2}}{25}.$

31. $4\frac{3}{4} \div 2.$ **33.** $\frac{10\frac{5}{8}}{5}.$ **35.** $\frac{18\frac{7}{8}}{3}.$ **37.** $\frac{50\frac{1}{2}}{50}.$

Inversion and Reciprocals. To *invert* means to turn upside down. Thus, $\frac{2}{3}$ *inverted* is $\frac{3}{2}$. $\frac{3}{2}$ is the *reciprocal* of $\frac{2}{3}$; and $\frac{2}{3}$ is the reciprocal of $\frac{3}{2}$. To state it another way, $\frac{2}{3}$ and $\frac{3}{2}$ are reciprocals. $\frac{4}{5}$ inverted is $\frac{5}{4}$; $\frac{4}{5}$ and $\frac{5}{4}$ are reciprocals. In paragraph *I*, chapter VII, we learned the meaning of a denominator of 1. That is, $\frac{2}{1} = 2$, $2 = \frac{2}{1}$; $5 = \frac{5}{1}$, $\frac{5}{1} = 5$. Hence, 2 (that is, $\frac{2}{1}$) inverted is $\frac{1}{2}$; or $\frac{1}{2}$ is the reciprocal of 2.

Dividing Whole Numbers by Fractions and Mixed Numbers. Suppose we wish to divide 2 by $\frac{1}{2}$. Looking

on the ruler, this means the number of $\frac{1}{2}$-inch lengths contained in a 2-inch length. We see at once that there are 4 $\frac{1}{2}$-inch lengths in a 2-inch length. Hence, $2 \div \frac{1}{2} = 4$. Or since a fraction is an indicated division, we can make the whole number the numerator and the fraction the denominator of a complex fraction. We can, therefore, set the problem down this way:

$$2 \div \tfrac{1}{2} = \frac{2}{\frac{1}{2}} = 4.$$

Similarly, we can show on the ruler that $\dfrac{3}{\frac{3}{8}} = 8$, since there are 8 $\frac{3}{8}$-inch lengths in a 3-inch length. From this we see that $\dfrac{2}{\frac{1}{2}}$ is the same as $2 \times \frac{2}{1}$, because $\dfrac{2}{\frac{1}{2}} = 4$ and $2 \times \frac{2}{1} = 4$. Similarly, $\dfrac{3}{\frac{3}{8}}$ is the same as $3 \times \frac{8}{3}$, because $\dfrac{3}{\frac{3}{8}} = 8$ and $3 \times \frac{8}{3} = \dfrac{\cancel{3} \times 8}{\cancel{3}} = 8$. Hence, *to divide a whole number by a fraction, we merely invert the divisor and multiply.*

EXAMPLE: *Divide 5 by* $1\frac{1}{4}$.

$$\frac{5}{1\frac{1}{4}} = \frac{5}{\frac{5}{4}} = 5 \times \tfrac{4}{5} = 4.$$

Find the value of the following expressions, checking the answers of the first three problems on the ruler. Do as many as possible without paper and pencil:

38. $\dfrac{1}{\frac{1}{2}}$. 40. $2 \div \frac{1}{8}$. 42. $\dfrac{4}{1\frac{1}{2}}$. 44. $\dfrac{6}{2\frac{1}{8}}$. 46. $100 \div 1\frac{1}{9}$.

39. $\dfrac{1}{\frac{1}{4}}$. 41. $\dfrac{3}{\frac{1}{8}}$. 43. $5 \div 1\frac{3}{4}$. 45. $\dfrac{7}{\frac{7}{8}}$. 47. $\dfrac{1000}{71\frac{3}{7}}$.

Division of Fractions and Mixed Numbers by Fractions and Mixed Numbers. Suppose we wish to divide

$\frac{3}{4}$ by $\frac{3}{8}$. On the ruler this means the number of times that a $\frac{3}{8}$-inch length is contained in a $\frac{3}{4}$-inch length. At once we see that this is 2 times. Hence, $\frac{3}{4} \div \frac{3}{8} = 2$. But we see that $\frac{3}{4} \div \frac{3}{8}$ is the same as $\frac{3}{4} \times \frac{8}{3}$, because $\frac{3}{4} \div \frac{3}{8} = 2$, and $\frac{3}{4} \times \frac{8}{3} = \frac{\cancel{3} \times \overset{2}{\cancel{8}}}{\cancel{4} \times \cancel{3}} = 2$. Therefore, *to divide a fraction by a fraction, we invert the divisor and multiply.*

EXAMPLE: *Divide $5\frac{1}{4}$ by $2\frac{1}{16}$.*

$$\frac{5\frac{1}{4}}{2\frac{1}{16}} = \frac{\frac{21}{4}}{\frac{33}{16}} = \frac{\overset{7}{\cancel{21}}}{\cancel{4}} \times \frac{\overset{4}{\cancel{16}}}{\underset{11}{\cancel{33}}} = \frac{28}{11} = 2\tfrac{6}{11}.$$

EXAMPLE: *Find the value of the following expressions, checking the answers to the first four problems on the ruler:*

48. $\dfrac{\frac{1}{2}}{\frac{1}{4}}$.

49. $\dfrac{\frac{1}{4}}{\frac{1}{8}}$.

50. $\dfrac{4\frac{1}{2}}{\frac{3}{4}}$.

51. $\frac{3}{8} \div \frac{1}{8}$.

52. $\dfrac{6\frac{1}{4}}{\frac{5}{8}}$.

53. $\dfrac{8\frac{1}{8}}{1\frac{1}{4}}$.

54. $2\frac{1}{6} \div 10\frac{1}{9}$.

55. $7\frac{2}{9} \div 17\frac{1}{7}$.

56. $101\frac{2}{3} \div 11\frac{1}{4}$.

57. $\dfrac{102\frac{7}{18}}{204\frac{7}{9}}$.

General Rule for Division of All Numbers. The following instances of division show that the general rule of inverting the divisor and multiplying applies to all numbers:

(a) $\frac{6}{2} = 3$, $\overset{3}{\cancel{6}} \times \frac{1}{\cancel{2}} = 3$.

(b) $\frac{\frac{6}{2}}{2} = \frac{3}{2}$, $\frac{\overset{3}{\cancel{6}}}{2} \times \frac{1}{\cancel{2}} = \frac{3}{2}$.

(c) $\frac{2}{\frac{6}{2}} = \frac{2}{3}$, $\cancel{2} \times \frac{2}{\underset{3}{\cancel{6}}} = \frac{2}{3}$.

(d) $\frac{\frac{3}{2}}{\frac{6}{2}} = \frac{\frac{3}{2}}{3} = \frac{1}{2}$, $\frac{\cancel{3}}{\cancel{2}} \times \frac{\cancel{2}}{\underset{2}{\cancel{6}}} = \frac{1}{2}$.

Therefore, remember that when you cannot divide in any other manner, *invert the divisor and multiply.*

Averages. Finding the *average* is common in the testing of material in a cotton mill. The meaning and use of *averages* is evident from the following:

EXAMPLE: *The rolls of lap from a certain picker are supposed to weigh* 50 *pounds.* 4 *laps weigh as follows:* $50\frac{1}{2}$ *pounds,* $49\frac{3}{4}$ *pounds,* $50\frac{1}{4}$ *pounds,* $49\frac{1}{2}$ *pounds. What is the average weight of the laps?*

$$\begin{array}{rl} 50\frac{1}{2} & 2 \\ 49\frac{3}{4} & 3 \\ 50\frac{1}{4} & 1 \\ \underline{49\frac{1}{2}} & \underline{2} \\ 198 & \frac{8}{4} = 2 \\ \underline{2} & \\ 200 & \end{array} \qquad \begin{array}{r} 50 \\ 4\overline{)200} \end{array}$$

Average weight = 50 pounds.

Thus, the average weight gives us a more accurate idea of the weight of the run of the laps than if we took the weight of one lap.

58. Find the average weight of a cut of cloth if four cuts weigh as follows: $15\frac{7}{8}$ pounds, $15\frac{3}{4}$ pounds, 16 pounds, $15\frac{7}{8}$ pounds.

59. It is desired to find the average weight of some fly frame bobbins. We find that 12 bobbins weigh $4\frac{1}{2}$ pounds. What is the average weight (in pounds) of these bobbins?

60. A certain cloth $30\frac{3}{4}$ inches wide between selvages contains 12 repeats of the warp pattern.

(*a*) How wide is each repeat of the warp?

(*b*) If there are 205 warp ends in each repeat, how many warp ends are there in one inch?

61. A $59\frac{1}{2}$-yard cut of a certain cloth weighs 18 pounds. How many yards are there to the pound?

62. 6 yards of sliver weigh $313\frac{1}{2}$ grains. What is the weight per yard?

63. If one yard of cloth weighs $\frac{3}{16}$ of a pound, how many yards should there be in a 57-pound roll?

64. If a loom weaves $3\frac{3}{4}$ yards of cloth in one hour, how long will be required to weave a double cut of 120 yards?

65. There are $3\frac{2}{10}$ yards of a certain kind of cloth to a pound. What is the weight of one yard?

66. How many yards of picker lap weighing $13\frac{1}{2}$ ounces per yard are there in a 54-pound roll of lap?

67. If a picker lap weighs $12\frac{1}{2}$ ounces per yard, how many yards are there in a $37\frac{1}{2}$-pound roll of lap?

68. Each card will produce $143\frac{1}{2}$ pounds of a certain kind of sliver in a day. How long will it require 9 cards to produce 12,915 pounds of this sliver needed for a certain order?

69. Two slubbers of 112 spindles each are to run on a certain roving. Each spindle will produce $7\frac{8}{10}$ pounds per day. How many days will be required to produce 10,920 pounds of this roving?

70. The average production per spindle of number 32 warp yarn on the spinning frames in a certain mill is $\frac{1}{5}$ of a pound per day. How many frames must be put on this yarn to produce 8832 pounds in 6 days, if each frame has 368 spindles?

71. A reed $43\frac{3}{4}$ inches long contains 980 dents. How many dents are there per inch?

72. A piece of ply yarn 12 inches long placed in the twist counter requires 270 turns to untwist it. What is its twist per inch?

CHAPTER XII

THE MEANING OF DECIMALS; ADDITION AND SUBTRACTION OF DECIMALS

All of our previous study of fractions has concerned *common fractions*. We now take up *decimal fractions*, or *decimals*. Decimals are fractions, the denominators of which are 10 or multiples of 10. However, in the decimal system of fractions we write $\frac{1}{10}$ as follows: .1. The dot before the 1 is called the *decimal point*, or *point*. Our starting place, therefore, in the study of decimals is that $\frac{1}{10}$ is written .1. From this we shall reason out everything about decimals. Practically all textile calculations are in the form of decimals rather than common fractions, because decimals are much more convenient to use.

We know that $100 \div 10 = 10$; that $10 \div 10 = 1$; that $1 \div 10 = .1$. That is to say, whenever we divide a number by 10, the first digit of the quotient "moves" one "place" to the right. How can we express in decimal form the fraction $\frac{1}{100}$? In other words, what is the quotient of $\frac{.1}{10}$? $\left(\frac{1}{100} = \frac{\frac{1}{10}}{10} = \frac{.1}{10}\right)$. We have seen that whenever we divide by 10 we "move" the first digit of the quotient one place to the right. Therefore, $\frac{1}{100}$ in the decimal system would be written . 1, leaving one blank place between the point and the digit. But we are apt to misunderstand how many places are intended to be left between the point and the digit. So, for each blank place intended, we put in a zero. Thus,

$\frac{1}{100}$ is written .01. Similarly, $\frac{1}{1000}$ is written .001; and $\frac{1}{10000}$ is written .0001. Now we see that we can make this statement: *To divide a number by* 10, *we "move" the decimal point one place to the left.* That is, $.1 \div 10 = .01$; $.01 \div 10 = .001$; $.001 \div 10 = .0001$.

Since to divide by 10 we move the decimal point one place to the left, and since $1 \div 10 = .1$, therefore, the decimal point with a whole number must be placed directly after its right-hand digit. That is, the decimal point with the whole number 1 must be placed like this: 1. Therefore, 1. means the whole number 1; 2. means the whole number 2; 10. means the whole number 10, and so on.

Since .1 means $\frac{1}{10}$, .2 must mean $\frac{2}{10}$, .9 must mean $\frac{9}{10}$; and since .01 means $\frac{1}{100}$, .09 must mean $\frac{9}{100}$. Similarly, .003 must mean $\frac{3}{1000}$, and .009 must mean $\frac{9}{1000}$.

What is the meaning of .10? It cannot mean $\frac{10}{10}$, because 1. means $\frac{10}{10}$. We know that .09 means $\frac{9}{100}$. Therefore, .10 must mean $\frac{10}{100}$. Similarly, .11 means $\frac{11}{100}$ and .99 means $\frac{99}{100}$.

Therefore, we see that *one digit* to the *right* of the decimal point means *tenths; two digits* to the *right* of the decimal point means *hundredths; three digits* to the *right* of the decimal point means *thousandths; four digits* to the *right* means *ten-thousandths,* and so on.

EXAMPLE: *Read the following decimal and write down its meaning as a common fraction:* .5590.

This decimal has four digits to the right of the decimal point. Therefore, it is read "five thousand five hundred ninety ten-thousandths." It means $\frac{5590}{10000}$.

PROBLEMS. *Read the following decimals and write their meanings in the form of common fractions. Reduce the common fractions. Do not confuse a period after a number with a decimal point:*

1. .9.	**11.** .98.	**21.** .09.	**31.** .990.	**41.** .099.
2. .8.	**12.** .97.	**22.** .07.	**32.** .977.	**42.** .081.
3. .7.	**13.** .91.	**23.** .06.	**33.** .800.	**43.** .075.
4. .6.	**14.** .77.	**24.** .05.	**34.** .750.	**44.** .050.
5. .5.	**15.** .75.	**25.** .04.	**35.** .500.	**45.** .025.
6. .4.	**16.** .50.	**26.** .03.	**36.** .499.	**46.** .010.
7. .3.	**17.** .45.	**27.** .02.	**37.** .390.	**47.** .009.
8. .2.	**18.** .25.	**28.** .01.	**38.** .250.	**48.** .005.
9. .1.	**19.** .11.	**29.** .999.	**39.** .101.	**49.** .001.
10. .99.	**20.** .10.	**30.** .998.	**40.** .100.	**50.** .0009.

Reduction of Decimals. From the preceding problems we see that .500 means the same thing as .5, because both mean $\frac{1}{2}$. Similarly, .1500 means the same as .15. Hence, to reduce a decimal ending in 0 or several 0's, we "drop" the final 0 or 0's. We could reduce, as we have seen, .15 to $\frac{3}{20}$. But $\frac{3}{20}$ is harder and more awkward to write than .15, and we would lose the advantage that the decimal system gives us.

Mixed Numbers in Decimal Form. 1.1 means $1\frac{1}{10}$; 2.5 means $2\frac{5}{10}$ or $2\frac{1}{2}$; 4.75 means $4\frac{75}{100}$ or $4\frac{3}{4}$; 5.90 means $5\frac{90}{100}$ or $5\frac{9}{10}$; 100.999 means $100\frac{999}{1000}$.

Read the following numbers. Reduce them to shorter decimals and then read your answer:

51. 10.10.	**53.** 25.290.	**55.** .50.	**57.** 19.080.
52. 12.20.	**54.** 1.8400.	**56.** 7.0500.	**58.** 2000.020200.

From the preceding problems we see that final 0's can be dropped without changing the value of the decimal. Since 1.1 means $1\frac{1}{10}$, 0.1 must mean 0 + .1, which merely means .1 or $\frac{1}{10}$. Similarly, 01. merely means 1.; 0005.5 merely means 5.5; 00009.9000 merely means 9.9. Hence, we see we can add or drop as many zeros before a whole number, or at the end of a decimal as we please without changing the value of the number.

EXAMPLE: *Change (or reduce) .8 to thousandths.* Answer: .800.

59. Reduce .500 to tenths.

60. Reduce 7.5 to hundredths.

61. Reduce 08.4020 to the shortest decimal.

62. Reduce 080.400 to the shortest decimal.

63. Reduce 099.7000 to the shortest decimal.

United States and Canadian Money. The unit (see paragraph *A*, chapter VII) of United States and Canadian money is the *dollar*. The dollar is made up of 100 *cents*. The *nickel* is 5 cents. The *dime* is 10 cents. The *quarter* of a dollar is, of course, 25 cents. The *half* dollar is, of course, 50 cents. The sign, \$, preceding a number means dollars; the sign, ¢, following a number means cents. Thus, \$2.10 means 2 dollars and $\frac{10}{100}$ dollars, but is read "2 dollars and 10 cents." We also see that it means 210 cents, but is never read this way. 10 cents can be written either \$.10 or 10¢. 1 cent could be written \$.01 or 1¢. .1¢ would mean $\frac{1}{10}$ of a cent.

Write the following amounts of money in the form of decimals, using the dollar sign:

64. Five dollars and one cent.

65. Six dollars and sixty-six cents.

66. One hundred and fifty-nine cents.

67. 269 cents.

68. Twenty-two dollars and eighty-nine cents.

69. 28 dollars and seven cents.

70. Five hundred fifty-seven dollars and eleven cents.

71. One thousand nine hundred six dollars and six cents.

72. Ten dollars ten and five-tenth cents.

73. Nineteen dollars nineteen and nine-tenths cents.

74. Ten dollars.

75. Ninety dollars.

76. Ten thousand five hundred ninety-six dollars.

Read the following:

77. $10\frac{1}{2}$¢. **78.** \$.105. **79.** \$14.56. **80.** \$5146.567.

Addition of Decimals

Suppose we wish to add $10.3 + 145.873$. $10.3 = 10.300$.

Hence, $10.3 + 145.873 = 10\frac{300}{1000} + 145\frac{873}{1000}$. Adding these we have:

$$\begin{array}{ll} 10 & \frac{300}{1000} \\ 145 & \frac{873}{1000} \\ \hline 155 & \frac{1173}{1000} = 1\frac{173}{1000} \\ & 1\frac{173}{1000} \\ \hline \multicolumn{2}{l}{156\frac{173}{1000} = 156.173} \end{array}$$

But we see that this gives the same sum as this:

$$\begin{array}{r} {}^{1} \\ 10.3 \\ 145.873 \\ \hline 156.173 \end{array}$$

Therefore, to add decimals and mixed decimals, place the decimal points under each other and add as in adding whole numbers.

EXAMPLE: *Add* 101.15, 549.675 *and* 1120.7593.

$$\begin{array}{r} 101.15 \\ 549.675 \\ 1120.7593 \\ \hline 1771.5843 \end{array}$$

PROBLEMS. *Add the following:*

81. 8.3 and 7.92.

82. 101.113 and .896.

83. 1.2, 14.57 and 146.399.

84. The labor cost of equipping 304 looms with tape selvage motion was as follows: first week, \$18.15; second week, \$49.60; third week, \$14.30; fourth week, \$26.40; fifth week, \$64.90; sixth week, \$64.90; seventh week, \$42.10. What was the total cost?

85. During one day, the following supplies were received by the supply room: 390 ft. 2″ double-ply belt, \$186.92; 5000 8-inch feeler bobbins, \$212.62; 232 ft. $1\frac{1}{2}$″ emery fillet, \$20.88. What was the total cost of supplies received during the day?

86. In one yard of a certain style of cloth the warp and size weigh .0915 pound and the filling .0845 pound. What is the weight of one yard?

SUBTRACTION OF DECIMALS

Suppose we wish to subtract 5.3 from 10.22. $5.3 = 5\frac{30}{100}$, $10.22 = 10\frac{22}{100}$.

$$\begin{array}{r} \overset{9}{\cancel{10}}\frac{22}{100} \\ -\ 5\frac{30}{100} \\ \hline 4 \\ +\ \frac{92}{100} \\ \hline 4\frac{92}{100} = 4.92 \end{array} \qquad \begin{array}{r} 100 \\ 22 \\ 122 \\ 30 \\ \hline \frac{92}{100} \end{array}$$

But we see that this gives the same result as this:

$$\begin{array}{r} \overset{9}{\cancel{10}}.{}^{1}22 \\ 5.3 \\ \hline 4.92 \end{array}$$

Subtract the following:

87. 27.89 from 32.011.

88. \$5.06 from \$6.01.

89. .891 from 1.0001.

90. If the warp and size in 1 yard of a certain style of cloth weighs .0809 pound and 1 yard weighs .1427 pound, what is the weight of the filling?

91. If the cost of supplies for section No. 19 of the weave room was \$39.17 and for section No. 22, having the same number of looms and making the same cloth, was \$21.90, what was the difference in the cost of supplies for the two sections?

92. If on a test run, a card delivered in 10 hours 175 pounds of sliver from 182 pounds of lap fed, and the top strippings weighed 4.92 pounds, what was the loss due to fly?

CHAPTER XIII

MULTIPLICATION OF DECIMALS

Suppose we wish to multiply 42.2 by 53.123. First, let us change these numbers to common fractions and multiply:

$$42.2 = \tfrac{422}{10}. \quad 53.12 = \tfrac{5312}{100}.$$

Therefore, $42.2 \times 53.12 = \dfrac{422 \times 5312}{10 \times 100}.$

$$\begin{array}{r} 5312 \\ \underline{422} \\ 10624 \\ 10624 \\ \underline{21248} \\ 2241664 \end{array} \qquad \begin{array}{r} 2241\tfrac{664}{1000} = 2241.664 \\ 1000\overline{)2241664} \\ \underline{2000} \\ 2416 \\ \underline{2000} \\ 4166 \\ \underline{4000} \\ 1664 \\ \underline{1000} \\ 664 \end{array}$$

Hence, $42.2 \times 53\ 12 = 2241.664$. But we see that this product is exactly the same as would be obtained by multiplying the numbers 42.2 and 53.12, as in ordinary multiplication and then placing a decimal point between the 1 and the 6, as shown at the left below:

$$\begin{array}{r} 5\ 3.1\ 2 \\ \underline{4\ 2.2} \\ 1\ 0\ 6\ 2\ 4 \\ 1\ 0\ 6\ 2\ 4 \\ \underline{2\ 1\ 2\ 4\ 8} \\ 2\ 2\ 4\ 1.6\ 6\ 4 \end{array}$$

We notice that 53.12 has two places to the right of the decimal point and 42.2 has one place to the right of the decimal point. We notice that 2241.664 has three places to the right of the decimal point. Hence, to multiply one decimal by another, we count the places to the *right* of the decimal point in *both* decimals and then "point off" the same number of places at the *right* of the product.

EXAMPLE: *Multiply* 52 *by* 12.6.

```
 1 2.6
   5 2
 -----
 2 5 2
6 3 0
------
6 5 5.2
```

Answer: 655.2.

PROBLEMS. *Multiply the following:*

1. 1.2×5.
2. 3.7×4.2.
3. 13.723×1.1.
4. 15.4×11.32.
5. 11.1×242.3745.
6. 1.25×3.1416.

Powers of Numbers. $2 \times 2 = 4$; $2 \times 2 \times 2 = 8$; $10 \times 10 = 100$; $10 \times 10 \times 10 = 1000$.

4 is the *second power* of 2; 8 is the *third power* of 2; 100 is the *second power* of 10; 1000 is the *third power* of 10. That is, the *second* power of a number is the product resulting from multiplying *two* of that number; the *third* power is the product resulting from multiplying *three* of that number.

The *second* power is often spoken of as the *square* of a number. Thus, 100 is the *square* of 10; or 10 *squared* is 100. The *third* power of a number is often called the *cube* of that number. Thus, 1000 is the *cube* of 10, or 10 *cubed* is 1000.

There is a short method of *indicating* powers, as follows: the second power or square is indicated by a ^{2} placed after the number, the third power by a ^{3}, and so on. Thus, $2^2 = 2 \times 2 = 4$; $10^3 = 10 \times 10 \times 10 = 1000$. 3^2 is read "3 squared," or "3 to the second power"; 10^3 is read "10 cubed," or "10 to the third power." 2 is the first power of 2; 10 is the first power of 10.

It will be observed that the *first* power of 10 has *one* 0; the *second* power has *two* 0's; the *third* power has *three* 0's, and so on.

It will also be observed that the first power of .1 has *one* decimal place; the *second* power of .1 ($.1 \times .1 = .01$) has *two* decimal places; the *third* power of .1 (.001) has *three* decimal places, and so on.

EXAMPLE: *Read the following and find the value of:* 3.2^3.

It is read "3 and two-tenths cubed" or "3 and two-tenths to the third power." The value $= 3.2 \times 3.2 \times 3.2 = 33.008$.

EXAMPLE: *Find the value of* $.10^3$.

Without putting anything on paper we see at once that $.10 = .1$; that $.10^3 = .1^3$; that since the third power is indicated, the result must have three decimal places; and that the answer must be .001.

Read and find the value of the following. Do as much work as possible in your head:

7. 3^3.	**9.** 1^1.	**11.** $.1^4$.	**13.** $.100^2$.	**15.** 10^4.
8. 9^2.	**10.** 1^3.	**12.** $.2^3$.	**14.** $.01^2$.	**16.** 100^2.

To Multiply by Powers of 10. If we perform the following multiplications, we shall obtain the products shown:

(*a*) $10 \times 2 = 20$. (*b*) $100 \times .21 = 21$. (*c*) $1000 \times 4.21 = 4210$. (*d*) $10000 \times 5.96712 = 59671.2$.

From these multiplications we see that *to multiply a number by a power of* 10 *we move that number's decimal point as many places to the right as the power of* 10 *has* 0's.

EXAMPLE: *Multiply* 21 *by* 10. Answer: 210.

EXAMPLE: *Multiply* 32.536 *by* 100. Answer: 3253.6.

Find the product of:

17. 52 and 100.	**20.** 1000 and .02.
18. 3.1416 and 100.	**21.** .830 and 100.
19. 437.5 and 1000.	**22.** .007 and 10000.

To Multiply by Powers of .1. If we perform the following multiplications, we shall obtain the products shown:

(*a*) $.1 \times 2. = .2$. (*b*) $.01 \times .21 = .021$. (*c*) $.001 \times 4215. = 4.215$. (*d*) $.0001 \times 59671.2 = 5.96712$.

From these multiplications we see that *to multiply a number by a power of .1 we move that number's decimal point as many places to the left as the power of .1 has decimal places.*

Find the products of:

23. 52 and .1.

24. 3.1416 and .01.

25. 7000 and .001.

26. .840 and .001.

27. 769.2 × .1.

28. 120 × .00001.

EXAMPLE: *A certain loom is making* 180 *picks per minute. How many yards will it produce in* 9.5 *hours if the cloth has* 50 *picks per inch?*

If this loom makes 180 picks in one minute, it will make 60 × 180 picks in 60 minutes or 1 hour. It will, therefore, make 9.5 × 60 × 180 picks in 9.5 hours. But each inch has 50 picks. Therefore, each yard contains 36 × 50 picks. And, therefore, the number of yards produced in 9.5 hours is the number of times that 36 × 50 is contained in 9.5 × 60 × 180.

$$\frac{9.5 \times 6\cancel{0} \times \overset{\cancel{36}}{\cancel{18}\cancel{0}}}{\cancel{36} \times \cancel{5}\cancel{0}} \qquad \begin{array}{r} {\scriptstyle 3} \\ 9.5 \\ 6 \\ \hline 57.0 \end{array}$$

Answer: 57 yards.

In the following problems use cancellation wherever possible:

29. If during the day a breaker picker delivered 48 rolls of lap, each roll containing 55 yards and each yard weighing 14.5 ounces, how many pounds of lap did the picker produce during the day?

30. How many pounds will the picker in the preceding problem produce in 5.5 days?

31. How many pounds of sliver will 10 cards produce in a day if each card produces 124.75 pounds?

32. How many pounds of sliver will a drawing frame of 3 heads, each head containing 4 deliveries, produce

in 5.5 days, if each delivery delivers 154.25 pounds of sliver in a day?

33. A certain slubber producing number one roving fills all its bobbins 3.6 times a day. How many pounds will it produce in a day if it has 96 spindles and each bobbin holds 44 ounces of roving?

34. If each spindle of a spinning frame produces .3 of a pound of number 23 warp yarn in 10 hours, how much will be produced in 10 hours on the following frames: 10 frames equipped with 216 spindles and 10 frames equipped with 224 spindles?

35. The weight of yarn on a full spinning bobbin of a certain size is 2.875 ounces. How many pounds will there be in one doff of a 320 spindle frame?

36. If 2.5 yards of cloth weigh one pound, how many yards will it take to weigh 25 pounds?

37. How many dents in a reed 40.5 inches long, if it has 22 dents per inch?

38. A piece of cloth counts 48 warp ends per inch and the cloth is 36.25 inches wide. How many warp threads in the cloth?

39. How many yards of cloth in a bale that weighs 420.25 pounds, if 2.5 yards of cloth weigh one pound?

40. If a tying-in machine will average tying 200.5 knots per minute, how many knots will it tie in 10 hours?

41. How many teeth in a gear 55 inches around, if there are 2.2 teeth per inch?

42. If one loom picker costs $.145, how much will the pickers cost for 28 sections a month, if each section uses 12 pickers?

43. If a certain kind and size of filling bobbins cost \$.032 each, how much money is invested in filling bobbins by a mill that has 50,000 of them on hand?

44. At \$1.625 each, how much will shuttles cost a mill per year if it uses 175 shuttles each month?

NOTE: The sign @ means "at." Change cents to dollars in solving the following problems. For instance: $9\frac{1}{2}$ cents should be changed to \$.09$\frac{1}{2}$ or \$.095. Your answers to the following problems should be stated in even cents. For instance, if the answer to a problem is \$1.525, make your answer \$1.53. If your answer is \$1.524, make your answer \$1.52.

45. What will be the cost of 22 barrels of sizing tallow @ $9\frac{1}{2}$ cents per pound, the barrels averaging 466 pounds each?

46. At $20\frac{1}{2}$ cents per cut for weaving, what will a weaver earn if he weaves 104 cuts of cloth in a week?

47. A workman getting $33\frac{1}{2}$ cents per hour worked $45\frac{1}{2}$ hours. How much did he earn?

48. On a certain style of cloth, seconds are worth $2\frac{1}{2}$ cents less per yard than first-quality cloth. How much will the mill lose on a 120-yard roll of seconds?

49. Drop wires for a loom are shipped 5 thousand per box @ \$6.25 per thousand. What will 30 boxes cost?

50. A $14\frac{1}{2}$-inch $\times$ $1\frac{1}{2}$-inch canvas lug strap cost $18\frac{3}{4}$ cents. How much will 250 cost?

51. At $8\frac{1}{2}$ cents a bier, how much will 100 shades of loom harness cost, 22 biers to the shade?

52. A weaver gets $18\frac{1}{2}$ cents a cut for weaving and wove 108 cuts in a week. He paid \$6.00 for board and \$5.75 for other expenses. How much remained?

53. If 280 pounds of starch at $4\frac{1}{4}$ cents per pound and 55 pounds of sizing tallow at $9\frac{1}{4}$ cents per pound

are used to make one kettle of size, what will be the cost of 8 kettles?

54. If it costs $12\frac{3}{4}$ cents a yard to manufacture a certain style of cloth, how much would a mill lose on 250 bales of seconds, 1010 yards to each bale sold at $12\frac{1}{4}$ cents a yard?

55. When cotton costs $24\frac{1}{2}$ cents per pound and waste sells for $5\frac{1}{4}$ cents per pound, how much does a mill lose on a bale of waste weighing 522 pounds?

56. A mill sold 100 bales of seconds at a loss of $2\frac{1}{4}$ cents a yard. The bales contained 825 yards each. How much was the loss?

57. A and B wove 4220 yards of cloth each in one week. $87\frac{1}{2}$ yards of A's cloth was second quality, and 426 yards of B's cloth was second quality. How much more was A's worth to the mill that week than B's, if the first-quality cloth sold at $13\frac{3}{4}$ cents a yard and the second-quality cloth sold at $3\frac{1}{4}$ cents a yard less than first quality?

58. A man makes $32\frac{1}{2}$ cents an hour. During the week he worked as follows: Monday, 9.5 hours; Tuesday, 10.5; Wednesday, 9.25; Thursday, 10.0; Friday, 11.75; Saturday, 4.75. How much did he make during the week?

59. A girl in the spinning room runs 10 sides. If she gets $27\frac{1}{2}$ cents per side per day, how much does she earn in $5\frac{1}{2}$ days?

60. If a slubber tender running 3 slubbers is paid 9 cents per hank, and the three hank clocks show the following hanks per week: 78.5, 77.2 and 79.4, what are his wages per week?

61. Figure up your own wages for last week.

CHAPTER XIV

DIVISION OF DECIMALS AND REDUCTION OF FRACTIONS TO DECIMALS

Division of Whole Numbers with a Decimal Quotient. Suppose we wish to divide 4 by 50 so that the quotient will be in decimal form. $\frac{4}{50} = \dfrac{4 \times 2}{50 \times 2} = \frac{8}{100} = .08.$

We see, however, that this same result might be obtained by setting the 4 and the 50 down in the usual manner for division as follows:

$50\overline{)4.}$ with a decimal point above the line — Place the decimal point after the 4 in its proper position. Place a decimal point above the line and directly above the decimal point after the 4.

$50\overline{)4.00}$ — Add 0's after the decimal point of the 4.

$\begin{array}{r} .08 \\ 50\overline{)4.00} \end{array}$ — Then divide as with ordinary division.

Suppose we wish to divide 75 by 4.

$$\begin{array}{r} 1\ 8\frac{3}{4} \\ 4\overline{)\ 7\ {}^{3}5\ {}^{3}} \end{array};\ \frac{3}{4} = \frac{3 \times 25}{4 \times 25} = \frac{75}{100} = .75.$$

Therefore, $75 \div 4 = 18.75$. But we could have obtained this same result by dividing as we did above:

$$\begin{array}{r} 1\ 8.\ 7\ 5 \\ 4\overline{)7\ {}^{3}5.{}^{3}0\ {}^{2}0} \end{array}$$

Suppose we wish to divide 239 by 17. We proceed as before.

```
        14.0588
   17)239.0000
      17
       69
       68
        1 00
          85
          150
          136
           140
```

We could keep on adding 0's to the dividend, but with this divisor and dividend we would never come to an end of the quotient. Each decimal place we would add to the quotient would make our quotient more nearly accurate, but we would never get an *exactly* accurate quotient. We can, however, get a quotient *sufficiently* accurate for any purpose "carrying" the quotient out to enough decimal places. This quotient, as will be observed, is "carried" to 4 decimal places. Suppose that 3 decimal places are sufficient for our purpose. We would carry the division to 4 decimal places and find that an 8 would occupy the 4th decimal place. Since 8 is larger than 5 we put down the result as 14.059. If, however, the 4th decimal place would be occupied by a number less than 5, we would put down the result as 14.058.

EXAMPLE: 12 *yards of roving weigh* 66 *grains. What is the number of the roving? Carry the number to* 2 *decimal places.*

```
       1.515
   66)100.000
      66
      34 0
      33 0
       1 00
         66
         340
```

Answer: The number of the roving is 1.52.

PROBLEMS. *If necessary, review yarn and roving numbering, chapter V:*

1. What is the number of the roving if 12 yards weigh 40 grains?

2. What is the number of the roving if 12 yards weigh 30 grains?

3. What is the number of the roving if 12 yards weigh 16 grains?

4. What is the number of the yarn if 120 yards weigh 60 grains?

5. What is the number of the yarn if 120 yards weigh 15 grains?

Reduction of Common Fractions to Decimals. It is always advisable to keep in mind the *decimal equivalents* of fractions that occur often in textile calculations. Practically all fractions in textile calculations are finally reduced to decimals.

EXAMPLE: *Reduce* $\frac{1}{3}$ *to a decimal.*

$$3\overline{)1.0^{1}0^{1}0^{1}0}\quad .3333$$

Answer: .333.

This is called a *repeating* decimal. Why? Why does it repeat?

Reduce the following fractions to decimals:

6. $\frac{1}{8}$. **7.** $\frac{1}{4}$. **8.** $\frac{1}{2}$. **9.** $\frac{5}{8}$. **10.** $\frac{3}{4}$. **11.** $\frac{7}{8}$. **12.** $1\frac{1}{8}$. **13.** $1\frac{1}{4}$.

Division of All Numbers. Suppose we wish to divide 4.5 by 5.

$$4.5 \div 5 = 4\tfrac{5}{10} \div 5 = \tfrac{45}{10} \div 5 = \tfrac{9}{10} = .9.$$

$$5\overline{)4.5}\quad .9$$

But we could have obtained this same result by dividing as shown at the left.

Suppose we wish to divide 420.864 by 51.2.

$$420.864 \div 51.2 = 420\tfrac{864}{1000} \div 51\tfrac{2}{10} = \tfrac{420864}{1000} \div \tfrac{512}{10} =$$

$$\frac{\overset{822}{\cancel{420864}}}{\underset{100}{\cancel{1000}}} \times \frac{\cancel{10}}{\cancel{52}} = \frac{822}{100}.$$

$$\begin{array}{r} 8.22 \\ 100\overline{)822.00} \\ \underline{800} \\ 22\ 0 \\ \underline{20\ 0} \\ 2\ 00 \\ \underline{2\ 00} \\ 0 \end{array}$$

Hence, $420.864 \div 51.2 = 8.22$.

But we could have obtained this same result by dividing as following:

```
51.2)420.864

           8.22
51.2.)420.8.64
      409 6
       11 2 6
       10 2 4
        1 0 24
        1 0 24
             0
```

There is *one* decimal place in the divisor. "Move" the decimal point of the divisor and dividend *one* place to the right. Place the decimal point of the quotient directly above the "moved" decimal point of the dividend. Remember that this moving of the decimal points merely multiplies the divisor and dividend by 10 which does not change the value of the quotient. Then divide as in ordinary division. We observe that our answers agree.

Division by Powers of 10 and Powers of .1.

14. Prove that to divide any number by a power of 10 we merely move its decimal point to the *left* as many places as the power of 10 has 0's.

15. Prove that to divide any number by a power of .1 we merely move its decimal point to the *right* as many places as the power of .1 has decimal places.

EXAMPLE: 120 *yards of yarn weigh* 50.22 *grains. What is the number of the yarn? Carry the answer to two decimal places.*

```
              19.912
50.22.)1000.00.000
         502 2
         497 80
         451 98
          45 82 0
          45 19 8
             62 20
             50 22
             11 980
```

Answer: Number of yarn is 19.91.

16. What is the number of the yarn if 120 yards weigh 35.5 grains?

17. If the calender roll of a picker is 28.27 inches around, how many times must it turn to deliver a yard of lap?

18. There is a tendency to number sliver according to the same system as roving. What would be the number according to the roving system of 62.2-grain sliver (sliver weighing 62.5 grains per yard)?

19. If the sand roll on a loom is 14.5 inches around, what portion of a complete turn does it make in taking up 1 inch of cloth?

20. If an intermediate fly frame spindle will produce 2.4 pounds of number 3.4 roving in 1 day, how many days will be required for 3 frames each with 96 spindles to produce 31,104 pounds?

21. A box full of bobbins weighs 250 pounds. The box weighs 75 pounds. How many bobbins are there in the box if a bobbin weighs 2.5 ounces?

22. If 198 cuts of cloth weigh 4009.5 pounds, how many pounds does each cut average?

23. How many yards of cloth will it take to weigh one pound, if 60.75 yards weigh 13.5 pounds?

24. How many belts 20.8 feet long will 312 feet of belting make?

25. If a tying-in machine ties on the average 250.5 knots per minute, how many minutes will be required to tie a warp with 3507 ends?

26. How many check straps in a lot weighing 130 pounds, if one strap weighs .325 pounds?

27. A certain size loom picker weighs .125 pounds. How many pickers in an 80-pound lot?

28. A cloth counts 47.8 in the sley and has 1673 ends in the warp. How many inches wide is the cloth?

29. A reed contains 969 dents, spread on 42.5 inches. How many dents per inch?

30. If a bale of cloth weighs 312.8 pounds and it takes 4.5 yards of this cloth to weigh one pound, how many yards are in the bale?

31. How many pieces of cloth 10.2 yards each will it take to make a 734.4-yard bale?

32. A piece of ply yarn 12 inches long placed in the twist counter requires 310 turns to untwist it. What is the number of twists per inch?

33. If a shipment of 390 feet of belting 2 inches wide costs $186.92, what is the cost of one foot?

34. If a shipment of 5000 feeler filling bobbins 8 inches long with top and base bushings cost $212.62, what is the cost of one bobbin?

35. If a shipment of 25 reeds $44\frac{1}{4}$ inches long and containing 1631 dents costs $59.40, what is the cost of each reed?

36. If a shipment of 1130 roving skewers costs $26.51, what is the cost of one skewer?

According to certain authorities, a liberal estimate of the average profits made by cotton mills that made any profit during recent years is $\frac{1}{8}$ of a cent a yard. On this basis solve the following problems.

37. The profit on how many 60-yard cuts of cloth is lost when 2 bobbins costing 4 cents each are run over by a truck and smashed?

38. The profit on how many 60-yard cuts of cloth is lost when 5 bobbins, each containing $1\frac{3}{4}$ ounces of plain carded yarn costing 33.5 cents a pound to manufacture, fall off a truck into the oil under a loom?

39. When 2 inches of 2-inch belting @ .479 cents a foot is wasted, the profit on how many 60-yard cuts of cloth is lost?

40. When a 1631-dent reed @ $2.38 is smashed, the profit on how many 60-yard cuts is wiped out?

41. On first-quality cloth of a certain style, a mill is making a profit of $\frac{1}{8}$ of a cent per yard. For second-quality cloth of the same style, the mill receives $2\frac{1}{4}$ cents less per yard than it does for first quality. This cloth has 60 picks per inch and the looms that weave this cloth make 180 picks per minute. How many 55-hour weeks will one loom have to run to make enough first-quality cloth to make up for the loss due to a weaver making seven 60-yard cuts of seconds in one week?

CHAPTER XV

ANALYSIS OF PROBLEMS; EQUATIONS

Equations. The use of equations often simplifies the thinking necessary in applying our knowledge of arithmetic to practical textile problems. An equation is a statement that two things are equal. This statement usually contains an equal sign, =. Thus, the following are equations: $\frac{1}{2} = \frac{2}{4}$; 36 inches = 1 yard. The part of the equation to the left of the equal sign is called the *left side* and the part to the right is called the *right side.*

Let us now see what we can do to an equation and still keep it true. 4 = 4 is a true statement or equation.

$4 = 4.$	
$14 = 4 + 10.$	Add 10 to each side, using a plus sign on the right side.
$14 - 3 = 4 + 7.$	Subtract 3 from each side, using a minus sign on the left side.
$\frac{14-3}{2} = \frac{4+7}{2}.$	Divide each side by 2.
$4 \times \frac{14-3}{2} = \frac{16+28}{2}.$	Multiply each side by 4.
$4 \times \frac{14-3}{2} = 22.$	Simplify (reduce) the right side. Now let us see if the equation is still true.
$22 = 22.$	Simply the left side.

Thus, we see that the equation is still true. Hence, we see that we can *add* the *same thing* to *both sides, subtract* the *same thing* from *both sides* of an equation, *multiply* and *divide both sides* of an equation by the *same thing* and the equation will still be true.

The sign $\therefore$ means "therefore."

EXAMPLE: *A sample of cloth $\frac{3}{4}$ of a yard long weighs 70 grains. What will be the weight of one yard?*

$\frac{3}{4}$ yard = 70 grains.

Here we understand that this statement means "the weight of $\frac{3}{4}$ of a yard = 70 grains."

$\therefore 1 \text{ yard} = \dfrac{70}{\frac{3}{4}}$ grains.

Dividing each side by $\frac{3}{4}$.

$\therefore 1 \text{ yard} = \frac{280}{3}$ grains = 93.33 grains.

EXAMPLE: *A sample of yarn $3\frac{1}{4}$ yards long is received by a mill. It weighs .65 of a grain. What is the number of the yarn?*

$3\frac{1}{4}$ yards = .65 grains.

$\therefore 1 \text{ yard} = \dfrac{.65}{3\frac{1}{4}}$ grains.

$$\therefore 120 \text{ yards} = 120 \times \frac{.65}{\frac{13}{4}} \text{ grains} = 120 \times \frac{\overset{.05}{\cancel{.65}} \times 4}{\cancel{13}} \text{ grains}$$

$$= 120 \times .2 \text{ grains} = 24 \text{ grains.}$$

```
     41.66
24)1000.
    96
     40
     24
     16 0
     14 4
      1 60
```

We see that this is a repeating decimal. Answer: the number of the yarn is 41.67.

Suggestions Regarding Written Work. One of the best ways to make your work easier is to do it neatly. "Sloppy" work often means "sloppy" thinking. Few of us are good penmen and few of us can keep our hands from shedding dirt, but we can all be neat more easily than we can be sloppy. It saves time. Here are some time-and-brain-saving suggestions:

1. Make simple letters and figures.
2. Draw straight fraction bars.
3. Put figures directly under each other.
4. Put fraction bars, equal signs, multiplication and addition signs in line.
5. Keep your pencil sharp and your eraser clean.

Below is a sample of poor penmanship, sweaty hands, but neat work:

$$3\tfrac{1}{4} \text{ yards} = .65 \text{ grains}$$

$$1 \text{ yard} = \frac{.65}{3\frac{1}{4}}$$

$$120 \text{ yards} = 120 \times \frac{.65}{\frac{13}{4}} \text{ grains} = 24 \text{ grains}$$

$$\frac{.65}{\frac{13}{4}} = \frac{4 \times \overset{.05}{\cancel{.65}}}{\cancel{13}} = .2$$

$$\begin{array}{r} 120 \\ .2 \\ \hline 24.0 \end{array}$$

EXAMPLE: *Owing to the drier climate in which one mill is located, its cloth gains moisture to the extent of .02 of its original weight in going to market. What shall be the yards per pound of cloth at the mill if it is to be 2 yards per pound at the market?*

Weight of 1 yard at market = weight of 1 yard at mill + .02 × weight of 1 yard at mill.

∴ $\frac{1}{2}$ pound = 1.02 × weight of 1 yard at mill.

∴ $\frac{1}{2}$ pound = weight of 1.02 yards at mill.

∴ 1 pound = weight of 2.04 yards at mill.

Answer: 2.04 yards per pound at the mill.

PROBLEMS:

1. In going through the slasher a certain warp takes on sizing equal to .05 of its original weight. If the warp yarn on a loom beam weighs 82 pounds, what is the weight of unsized warp on the beam?

2. A certain number of roving contracts .035 of its length in being twisted. What is the length required to produce 840 yards of this roving?

3. If 16 check straps weigh $3\frac{1}{4}$ pounds, how many are there in a 130-pound shipment?

4. A loom running $9\frac{1}{2}$ hours wove 57 yards. How many yards will it weave in 55 hours?

5. If 16 loom bolts weigh $3\frac{3}{4}$ pounds, how many are there in a 200-pound box if the empty box weighs 20 pounds?

6. A size kettle $\frac{3}{5}$ full contains 225 gallons of size. How many gallons does the kettle hold?

7. If .05 of the cotton fed into the cards goes to waste, how much lap must be fed to make 2500 pounds of sliver?

8. A 28-inch sample of cloth weighs $3\frac{1}{2}$ ounces. How many yards are there to a pound?

9. What is the number of the yarn if a sample of it $5\frac{1}{3}$ yards long weighs .64 grains?

10. If .07 of a certain grade of cotton becomes waste, how many pounds of cotton are required to manufacture 100,000 pounds of cloth?

11. If 8 loom pickers weigh one pound, what will 1000 cost at $1.25 per pound?

12. At $1.25 a pound, what will 100 yards of slasher cloth be worth, if one yard weighs 14 ounces?

CHAPTER XVI

PERCENTAGE

The word *percent* means "by the hundred." Thus, when a card makes 5 percent waste, 5 out of every hundred pounds is waste. If a man's wages are increased 6 percent, for every hundred cents he was receiving he now receives 6 cents more.

To put it another way: when a card makes 5 percent waste, $\frac{5}{100}$ of all the cotton fed is waste. If a man's wages are increased 6 percent, $\frac{6}{100}$ of his former wages are added to his former wages.

Hence, 5 percent means .05; 6 percent means .06. The sign % means percent and is read "percent."

EXAMPLE: 200 *pounds of cotton are fed to a card in a day. If the card makes* 5% *waste, how much waste may we expect from a day's run?*

5% of 200 pounds means $.05 \times 200$ pounds = 10 pounds.

EXAMPLE: *A spinner is to receive an increase of* 10% *in her wages. If she is now receiving* 25 *cents per side per day, what will she receive?*

10% of 25 cents means $.10 \times 25$ cents = 2.5 cents.

$\therefore$ she will receive 25 cents + 2.5 cents = 27.5 cents.

PROBLEMS:

1. A spinner earns $18.15 a week and saves $33\frac{1}{3}\%$ of it. How much does she save in a week?

2. If a mill makes 480,220 yards of cloth in a week, 95% of it first quality, how many yards of seconds were made?

3. The gearing of a spinning frame is figured to put 28.5 twists per inch into a certain yarn. But the yarn contracts 3% due to twisting. Therefore, how many twists per inch are put into the yarn?

4. A certain mill from its experience figures on $12\frac{1}{2}\%$ of its cotton going into waste and seconds. How much first-quality cloth does it expect from a 500-pound bale of cotton?

100 Percent. Since 90% means $\frac{90}{100}$ or .90, 100% must mean $\frac{100}{100}$ or 1.00. Therefore, 100% of anything is the *whole* of it or *all* of it. When we speak of 100% production, we usually mean the amount of material that would be produced in a given time if the machine were running continuously without stopping for cleaning, oiling, doffing, etc.

Finding the Percent

Base. 4 is what percent of 5? This question really means: What number multiplied by 5 will give 4? We can find this number by using equations:

The unknown number $\times$ 5 = 4. Dividing both sides by 5:

The unknown number $= \frac{4}{5} = .80$.

Hence, 4 is 80% of 5. And, of course, 5 is 100% of 5. 5 is the *base*. The base in any percentage problem is always the number that is 100%. Hence, we see that *to find what percent any number is of the base we divide the number by the base.*

Example: *100% production for a card running a certain weight and grade sliver is 550 pounds per week. What percent production is obtained when the card produces 522 pounds?*

Base is 550.

$$\begin{array}{r} .9490 \\ 550\overline{)522.000} \\ 495\ 0 \\ \hline 27\ 00 \\ 22\ 00 \\ \hline 5\ 000 \\ 4\ 950 \\ \hline 500 \end{array}$$

Answer: 94.9% production.

NOTE: The decimal in the 3rd place in the quotient is $\frac{9}{1000}$. But $\frac{9}{1000}$ is $\frac{9}{10}$ of $\frac{1}{100}$ which means that it is .9 of 1 percent.

5. 100% production for a certain breaker picker running 15-ounce lap is 13,000 pounds for 55 hours. What is its percent of production if it delivers 11,700 pounds in 55 hours?

6. A drawing frame of 4 heads, 4 deliveries to a head, produced in a week of 55 hours 17,600 pounds of 65-grain sliver. Each delivery of this frame, if it could run continuously for 10 hours, would produce 250 pounds. What percent of production was obtained?

Decimal Fractions of Percent. We have seen that 1% = .01. What is the meaning of .1%? .1% must mean $\frac{1}{10}$ of 1%. Hence, $.1\% = .1 \times 1\% = .1 \times .01 = .001$.

EXAMPLE: *Express .03% as a plain decimal.*

$.03\% = .03 \times .01 = .0003$. Answer: .0003.

7. Last week the percent of production for the drawing frames was 80%. The week before last its percent of production was 79.5%. How much did the percent of production increase?

8. For the week ending April 9th the drawing frame production was 80.5%. During the week ending April 16th, the production was 79.7%. What was the decrease in percent of production?

In figuring percentage it is necessary that you first select the proper base.

EXAMPLE: *During the week ending April 9th, the pickers of a certain mill produced 234,000 pounds. 100% production for this weight of lap is 260,000 pounds. The week ending April 16th, the pickers produced 238,000 pounds. How much did production increase?*

234,000 ÷ 260,000 = .90 = 90%. 238,000 ÷ 260,000 = .915 = 91.5%. Hence, increase in *percent of production* = 91.5% − 90% = 1.5%.

We might also obtain the same result with less work as follows: Increase in pounds = 11,900 − 11,700 = 200. 200 ÷ 13,000 = .015 = 1.5%.

Increase in *production*, based upon the first week's production, was 200 ÷ 11,700 = .017 = 1.7%. Be sure you select the proper base for the result desired.

9. 100% production for the frames of a certain spinning room running on number 11½ warp yarn is 42,000 pounds per week. During the week ending December 2nd it produced 37,800 pounds. The following week it produced 38,010 pounds. (*a*) What was the increase in percent of production? (*b*) What was the increase in production.

10. In 6 days 380 looms wove 114,912 yards of cloth. What percent did the looms weave if 52.5 yards per loom per day is 100% production? *Hint:* Use cancellation.

11. A loom supposed to run 160 picks per minute, on account of the belt being slack, is running 152 picks per minute. What percent of production is it losing?

12. A tying-in machine tying 250 knots a minute tied 60 warps, 2125 knots each, in 10 hours. What percent of the time was the machine stopped? *Hint:* Use cancellation.

13. If 5844 pounds of cotton are used to manufacture 5113.5 pounds of first-quality cloth, what percent went into waste and seconds?

14. In one year a mill used 6,768,600 pounds of cotton and manufactured 5,922,525 pounds of first-quality cloth. What percent of the cotton went into waste and seconds?

15. In weaving a certain style of cloth it was found that a 63-yard cut of warp from the slasher made a 60-yard cut of cloth. What was the percent of contraction of the warp based on the original length of warp?

16. In weaving a certain style of cloth which is 36 inches wide, the width of the warp in the reed is $39\frac{1}{4}$ inches. What is the percent of contraction in the filling?

Finding the Base

EXAMPLE: *The carding room report of a certain mill for one week shows 82,500 pounds of a certain number of roving. This is stated as 90.5% production. What is 100% production?*

$$90.5\% = 82{,}500. \quad \therefore\ 1\% = \frac{82{,}500}{90.5}.$$

$$\therefore\ 100\% = \overset{20}{\cancel{100}} \times \frac{82{,}500}{\underset{18.1}{\cancel{90}.5}} = 91{,}160.$$

Answer: 91,160 pounds.

But this same result could have been obtained more quickly as follows: From the preceding we see that $100\% = \dfrac{100 \times 82{,}500}{90.5}$. Dividing both numerator and denominator by 100: $100\% = \dfrac{82{,}500}{.905}$. Hence, we would set this problem down as follows:

90.5% = .905. $.905.\overline{)82,500.000.}$ with quotient 91 160., dividing as in ordinary long division.

EXAMPLE: *The pay for a certain style cloth was increased* 10%. *The pay is now* 27½ *cents per cut. What was the pay per cut before it was increased?*

$$110\% = 27.5.$$

Following the same reasoning as in the previous example, we divide as follows:

```
          25.
1.10.)27.50.      Answer: 25 cents.
      22 0
       5 50
```

17. How many pounds of cotton will be required to manufacture 126,000 pounds of finisher lap if .24% of the cotton is removed in going through the pickers?

18. If cotton loses 5% in carding, how many pounds of lap will be required to make 5187 pounds of card sliver?

19. If a loom is stopped 15% of the time and weaves 42.2 yards of cloth in a day, how many yards would it weave if it did not stop?

20. A certain loom beam contains 165 pounds of sized warp yarn. 8% was added to the original weight of the yarn by the slasher. How much unsized warp yarn does the beam contain?

21. 3 yards of sized warp yarn from a sample of cloth weigh 2.14 grains. If 7% of size has been added to the warp, what is the number of the yarn?

22. What must be the length of warp from the slasher to make a 60-yard cut of cloth if the warp contracts 6½% in weaving?

23. What must be the width of warp in the reed if the cloth is to be 36 inches wide and the contraction in filling of this style of cloth is 6%?

Miscellaneous Problems

24. The supplies for section 1 for 1 month cost $58.52. The supplies for section 2 for the same month cost $63.05. Both sections had the same number of looms on the same goods. What percent higher was the cost of supplies for section 2 than for section 1?

25. A weekly cloth room report is as follows: first-quality cloth baled, 450,832 yards; second-quality cloth baled, 23,728 yards. What percent of the cloth was second quality?

26. In one week a mill manufactured 473,714 yards of cloth. 4% of it was seconds. $1\frac{1}{2}$% was shorts and the remainder was first quality. How many yards of each quality were manufactured?

27. One kind of sizing compound contains 39 percent water, 34 percent tallow, 9 percent starch, 17 percent crude glycerine and one percent ash. How many pounds of each are required to make a batch of 2550 pounds of compound?

28. A cut of cloth whose weight is 22 pounds contains 8.8 pounds of filling. Find the percent of warp in the cloth.

29. 1080 bales of cotton were stored in a warehouse which caught fire. The insurance company estimated that 15% was destroyed by fire. How many bales were saved?

30. In a weave room there are 840 looms, 35% of them making sheeting, 40% making drills and the re-

mainder of them making sateens. How many looms are there on each style?

31. If there are 80 employees in a weave room and 15% of them are loom fixers, how many loom fixers are there in the room?

32. In weaving a certain style sheeting it was found that the contraction was 6% in length. How many yards of this style of cloth will 63.6 yards of warp make?

33. Since getting an increase of 9% a fixer's wages are $5.45 a day. How much was he earning before the increase?

34. If 4% of the cloth made on a loom in one week was second quality and the first-quality cloth made was 312 yards, how many yards were made on the loom?

35. In 1890 the United States had approximately 14,000,000 cotton spinning spindles. In 1923 it had approximately 36,000,000 cotton spinning spindles. What percent did the spindles increase?

CHAPTER XVII

MEASURES OF WEIGHT, LENGTH, TIME, AREA AND VOLUME

Most of the following units of measure (see chapter VII) are in common use in a cotton mill. You are already familiar with most of these units of measure. The abbreviations and signs that stand for the units named are given in parentheses ( ).

Weight Measure

7000 grains (gr.) = 1 pound (lb.) or (lbs.)
16 ounces (oz.) or (ozs.) = 1 pound
2000 lbs. = 1 ton

Linear Measure

12 inches (in.) or (″) = 1 foot (ft.) or (′)
3 feet (ft.) = 1 yard (yd.)
36 inches = 1 yard
120 yards = 1 skein
840 yards = 1 hank
5280 feet = 1 mile

Time Measure

60 seconds = 1 minute (min.)
60 minutes = 1 hour (hr.) or (hrs.)
24 hours = 1 day
7 days = 1 week
365 days = 1 year

Problems:

1. How many grains in an ounce?

2. How many skeins in a hank?

3. How many minutes in 10 hours?

EXAMPLE: *How shall we measure .8 of a yard with a yard stick?*

There are 36 inches in one yard. $.8 \times 36$ in. = 28.8 in. A foot rule or a yard stick is divided into $\frac{1}{2}''$, $\frac{1}{4}''$, $\frac{1}{8}''$ and $\frac{1}{16}''$ spaces and sometimes into $\frac{1}{32}''$ spaces.

$$.8 \text{ in.} = .8 \times \tfrac{16}{16} \text{ in.} = \frac{12.8 \text{ in.}}{16} \text{ or practically } \tfrac{13}{16} \text{ in.}$$

$$\therefore .8 \text{ yd.} = 28.8 \text{ in.} = 28\tfrac{13}{16} \text{ in. approximately.}$$

4. Reduce 63.7 yards to yards, inches and sixteenths of an inch.

5. Reduce 58.85 yards to yards, inches and eighths of an inch.

6. Reduce 18.36 hours to hours and minutes.

7. Reduce 25.7 lbs. to pounds and ounces.

8. Reduce 210 yards to inches.

9. Reduce 44 oz. to grains.

10. Reduce 11 hanks to yards.

EXAMPLE: *Reduce 2 lbs. 6 oz. to pounds.*

$$2 \text{ lbs. } 6 \text{ oz.} = 2\tfrac{6}{16} \text{ lbs.} = 2\tfrac{3}{8} \text{ lbs.} = 2.375 \text{ lbs.}$$

11. Reduce 2 hrs. 33 min. to hours.

12. Reduce 10 yards 24 inches to yards.

13. Reduce 9 lbs. 7 oz. to pounds.

EXAMPLE: *Reduce 153 minutes to hours and minutes.*

$$\begin{array}{r} 2\tfrac{33}{60} \\ 60\overline{)153} \\ \underline{120} \\ 33 \end{array} \qquad 153 \text{ minutes} = 2\tfrac{33}{60} \text{ hours} = 2 \text{ hrs. } 33 \text{ min.}$$

14. Reduce 44 ounces to pounds and ounces.

15. Reduce 276 inches to yards and inches.

16. Reduce 305 minutes to hours and minutes.

17. Reduce 52,500 grains to pounds.

18. Reduce 64,750 grains to pounds.

19. Reduce 7840 yards to hanks.

20. Reduce 468,720 inches to hanks.

Compound Addition. Such quantities as 2 lbs. 3 oz. are *compound quantities* because they are made up of more than one kind of unit. The following will make clear the method of adding compound quantities.

EXAMPLE: *What is the total weight of three laps if they weigh as follows:* 46 *lbs.* 9 *oz.,* 47 *lbs.* 1 *oz.,* 46 *lbs.* 11 *oz. and* 46 *lbs.* 12 *oz.*

46 lbs.	9 oz.	
47	1	
46	11	
46	12	
185	33 oz. = 2 lbs. 1 oz.	
2 lbs.	1 oz.	
187 lbs.	1 oz.	Answer: 187 lbs. 1 oz.

Compound Subtraction.

EXAMPLE: *From a double cut of cloth* 122 *yds.* 27 *in. long, a piece* 8 *yds.* 33 *in. long had to be cut. How much remained?*

121	36	
122 yds.	27 in.	
	63	
−8	33	
113 yds.	30 in.	Answer: 113 yds. 30 in.

Compound Multiplication.

EXAMPLE: *How many yards in a bale of cloth containing 21 pieces, 40 yds. 29 in. long?*

$$\begin{array}{r} 40 \text{ yds.} \\ \underline{21} \\ 40 \\ \underline{80} \\ 840 \text{ yds.} \\ \underline{16 \text{ yds. } 33 \text{ in.}} \\ 856 \text{ yds. } 33 \text{ in.} \end{array} \qquad \begin{array}{r} 29 \text{ in.} \\ \underline{21} \\ 29 \\ \underline{58} \\ 609 \text{ in.} \end{array} \qquad \begin{array}{r} 16\frac{33}{36} \\ 36)\overline{609} \\ \underline{36} \\ 249 \\ \underline{216} \\ 33 \end{array}$$

Answer: 856 yds. 33 in.

Compound Division.

EXAMPLE: *The rear roll of a slasher requires about* 4 *yards of slasher cloth, to cover it. We have a roll of slasher cloth containing* 15 *yds.* 34 *in. How many pieces can we cut from this roll and exactly how long will each piece be?*

We see that there is almost enough to make four 4-yd. pieces. We shall divide it into 4 pieces.

$$\begin{array}{r} 3\frac{3}{4} \text{ yds. } 8\frac{2}{4} \text{ in.} \\ 4)\overline{15 \text{ yds. } 34 \text{ in.}} \end{array} \qquad \tfrac{3}{4} \text{ yd.} = \tfrac{3}{4} \times 36 \text{ in.} = 27 \text{ in.}$$

$$\begin{array}{lcr} \therefore\ 3\frac{3}{4} \text{ yds.} & = & 3 \text{ yds. } 27 \text{ in.} \\ \therefore\ 8\frac{2}{4} \text{ in.} & = & \underline{8\frac{1}{2} \text{ in.}} \\ & & 3 \text{ yds. } 35\frac{1}{2} \text{ in.} \end{array}$$

Answer: Each piece 3 yds. $35\frac{1}{2}$ in. long.

21. A waste test report for 4 breaker pickers is as follows: 146 lbs. 8 oz., 140 lbs. 4 oz., 152 lbs. 12 oz., 130 lbs. 8 oz. Find the total waste for the 4 pickers.

22. The waste report for nine slashers for the day is as follows: 2 lbs. 4 oz., 3 lbs., 2 lbs. 11 oz., 4 lbs. 1 oz., 2 lbs. 14 oz., 5 lbs. 1 oz., 3 lbs. 13 oz., 4 lbs. 9 oz., 6 lbs. 2 oz. Find the total pounds for the day.

23. To clothe the cylinder of a certain card 275′ 9″ of 2″ clothing filleting is required. To clothe the cylinder of another card 307′ 8″ of the same filleting is required. How much 2″ filleting will be required for the cylinders of both cards?

24. The gross weight of a bale of cloth is 462 lbs. 11 oz. The burlap and ties weigh 7 lbs. 14 oz. How many lbs. of cloth in the bale?

25. A mechanic started a job at 7:45 A.M., and finished at 11:10 A.M. How long did the job take?

26. From a double cut 121 yds. 20 in. long a piece 10 yds. 24 in. had to be cut. How much cloth was left in the piece?

27. Find the number of feet of pipe necessary to make 24 humidifier drain pipes if each drain pipe is to be 10′ 1″ long.

28. How many pounds of yarn in 540 cops if each cop weighs 3 lbs. 3 oz.?

29. How many yards of slasher cloth will be required to cover the rear and front rolls of 4 slashers if the rear rolls each require 3 yds. 27 in. of 16-oz. slasher cloth and the front rolls each require 4 yds. 30 in. of 12-oz. slasher cloth?

30. A space 29′ 6″ long is to contain 8 bobbin bins. How long will each bin be?

Circular Measure

If we hold a piece of chalk against the face of a moving pulley the chalk will mark a *circle* on the pulley. The *center of the circle* will be at the center of the shaft on which the pulley runs. The distance

from any point on the circle through the center of the circle to the chalk mark on the opposite side of the pulley is the *diameter* of the circle. The *length* of the chalk mark on the face of the pulley is the *circumference* of the circle. The drawing to the left makes this clear. The *radius* is the distance from the center to the circumference. Hence, the radius is half of the diameter.

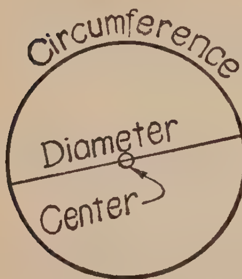


Figure 1

Finding the Circumference. If you should take a steel tape measure and measure very accurately the diameter and the circumference of a pulley, you would find that the circumference is a little more than 3 times the diameter. In all our calculations we shall consider that:

circumference = 3.1416 × diameter.

This is sufficiently accurate for our work. We shall use the abbreviations (cir.) or (circum.) for circumference and (dia.) for diameter. We will use these terms repeatedly.

EXAMPLE: *What is the circumference of a pulley whose diameter is 36″.*

3.1416 × 36 = 113.098. Answer: 113.098 inches.

31. What is the circumference of a front roll on a spinning frame if its diameter is 1″?

32. What is the circumference of the calender roll of a card if the roll is 2″ in diameter?

Revolutions. The word *revolution* means one complete turn. If you should take hold of a pulley and

turn it until your hand is back in the exact spot it was when you started to turn the pulley, the pulley has made one revolution.

33. The front roll of a certain slubber is $1\frac{1}{4}''$ in diameter. How many inches of roving does it deliver in a minute if during the minute the roll makes 200 revolutions?

34. If the calender roll of an intermediate picker is $9''$ in diameter, how many yards of lap will the picker deliver in a minute if the calender roll makes $7\frac{1}{4}$ revolutions in one minute?

Finding the Diameter. Since the cir. = 3.1416 × dia. we can divide both sides of the equation by 3.1416 and obtain the following equation:

$$\text{diameter} = \frac{\text{circumference}}{3.1416}.$$

35. The circumference of a pulley is $23\frac{9}{16}$ inches. What is the diameter?

36. What is the diameter of a slasher cylinder, if the circumference is 15 ft. $8\frac{1}{2}$ in.?

37. (*a*) Find the diameter of a pulley whose circumference is 18 ft. $10\frac{3}{4}$ in.

(*b*) If the circumference of a shaft is $7\frac{27}{32}$ in., what is the diameter?

38. In order to increase the speed of a certain spinning room line shaft we wish to increase to a maximum the size of the pulley on the main shaft which runs the line shaft. The distance from the spinning room ceiling to the top of the main shaft is $20\frac{1}{4}''$. The main shaft is $11''$ around. The belt on the main shaft is $\frac{1}{2}''$ thick. What is the largest size pulley that we may place on

the main shaft and still give at least ½″ clearance between the belt and the ceiling? *Hint:* Make a drawing of this problem before starting to solve it.

Square or Area Measure

Thus far we have discussed measures of length, weight and time. Now we come to measures of *surface* or *area.* The *length* of the *square* in figure 2 is 1 inch. The *width* of the *square* is also 1 inch. How much surface or area does it have? Any figure that is 1 inch long and 1 inch wide is said to have an area of 1 *square inch.*

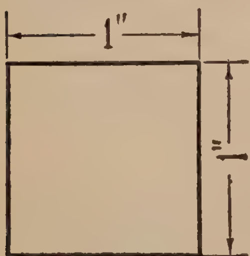


Figure 2

Suppose we should divide this square into 4 equal but smaller squares as shown in figure 3. We see at once that the length and width of each of these little

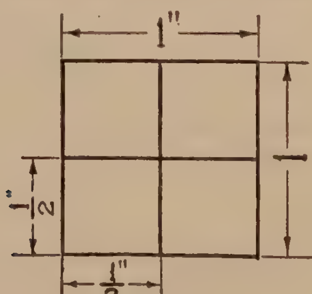


Figure 3

squares is ½ inch. How much area does each of the little squares have? Since the large square has 1 square inch of area, each small square must have ¼ of a square inch of area.

Now let us consider figure 4, which is 4″ long and 3″ wide and divided into squares 1″ long and 1″ wide. The lower row contains four squares, and since the figure is 3″ wide, the whole object contains 3 × 4 squares = 12 squares. To prove this we can count the squares. We find that there are 12 squares. Hence, the number of square inches in any figure that has four square corners = number of inches in its length × number of inches in

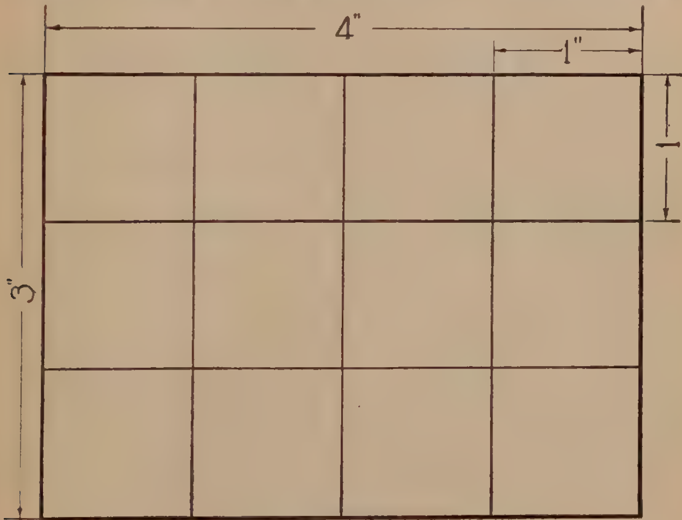


Figure 4

its width. We also see that this is true of the little squares in figure 3. We said that each little square has an area of $\frac{1}{4}$ of a square inch. The length and width of each square is $\frac{1}{2}$ of an inch. Now multiply $\frac{1}{2} \times \frac{1}{2}$ and we get $\frac{1}{4}$. A figure with four square corners is called a *rectangle*. A square is a rectangle with its width equal to its length. Hence,

the area of any rectangle = width × length.

A square with a length of 1 inch is said to be 1 *inch square.* A square with a length of 2 inches is said to be 2 *inches square.* A surface 2 *inches square* has 4 *square inches* of area. Be sure you understand the distinction between *inches square* and *square inches.*

39. How many square inches in a sample of cloth 3 inches square?

40. How many square inches in a sample of cloth 4 inches square?

41. How many square inches in a sample of cloth 9 inches square?

42. Back in chapter XIV we discussed powers of numbers. Why is the second power of a number called the square of the number?

43. How many square inches in a sample of cloth 10 inches square?

44. How many square inches in a sample of cloth 12 inches square?

45. What is the area of a sample of cloth 27″ wide and 12″ long?

A square with a length of 1 foot has an area of 1 *square foot* and is said to be 1 *foot square*. A square with a length of 1 yard has an area of 1 *square yard* and is said to be 1 *yard square*.

46. How many square inches in a square foot?

47. How many square inches in a square yard?

EXAMPLE: *How many square inches in a 1-yard piece of cloth that is 40″ wide?*

Length = 1 yd. = 36″. Width = 40″. Square inches = 40 × 36 = 1440.

48. How many square inches in a 1-yard length of cloth that is $48\frac{1}{2}$ inches wide?

49. How many square inches of cloth in a piece of cloth that is 16.5 inches long and 11 inches wide?

50. How many samples of cloth 4″ wide and 5″ long can be cut from a yard of cloth that is 40″ wide?

51. How many square feet are there in one square yard?

52. Find the square feet of floor space in a supply room 72 ft. 6 in. long and 27 feet wide. *Hint:* Reduce the inches to fractions of feet.

The supply room in the preceding problem would be spoken of as: 72′ 6″ by 27′ or 27′ by 72′ 6″. Instead of the word "by," the dimensions are often written: 27′ × 72′ 6″.

In the following problems, disregard the amount of metal needed for seams or laps:

53. Find the number of square feet of copper that will be required to cover a mixing platform 4′ 8″ × 2′ 6″.

54. How many square inches of sheet iron will be required to make a quill can without a top of the following dimensions: bottom 8″ × 12″, depth 24″. *Hint:* First find the areas of the sides and bottom. Then add to find total area.

55. How many square feet of sheet copper will be required to line the bottom, ends and sides of a size box, whose inside dimensions are 66″ long × 28″ wide × 12″ deep?

56. Find the number of square inches of sheet iron that will be required to make a quill can $12\frac{1}{2}''$ × $8\frac{1}{2}''$ × $24\frac{1}{2}''$ high, with a bottom, but no top.

57. How many square feet of sheet iron will be required to line a filling chute 22″ × 22″ × 38′ high?

58. A certain card is 63 inches wide and 10′ $3\frac{1}{2}''$ long. How many square feet of floor space does it require?

Areas of Circles. The area of a circle is equal to 3.1416 times the diameter squared divided by 4. Thus:

$$\text{area of a circle} = 3.1416 \times \frac{\text{dia.}^2}{4}.$$

59. From the preceding, prove that:

$$\text{area of a circle} = .7854 \times \text{dia.}^2$$

EXAMPLE: *Find the area of a circle 2′ 6″ in diameter.*

$2' \ 6'' = 30''$. $30^2 = 30 \times 30 = 900$. $\therefore .7854 \times \text{dia.}^2$
$= .7854 \times 900 = 706.86$.

Area of circle = 706.86 square inches.

60. How many square inches of copper will be required to make a head for a slasher flue 14 inches in diameter?

61. (*a*) What is the area of one head of a slasher cylinder, if the diameter is 9 ft.?

(*b*) What is the total pressure on the head of a slasher cylinder when the pressure is 10 pounds per square inch?

62. How many square feet of copper will be needed to line the head of a size kettle whose diameter is 48 inches?

CUBIC OR VOLUME MEASURE

The object shown in figure 5 is a *cube*. All of its sides are squares. Any figure with its sides made of squares is a cube. The sides of the cube in figure 5 are 1 inch squares. Hence, the cube in figure 5 is 1″ long, 1″ wide and 1″ high (or deep). A cube 1″ long, 1″ wide and 1″ high is said to have a *volume* of 1 *cubic inch*. Other names for volume are *cubic capacity*, *capacity*, *cubic contents* or *contents*. If the sides of this cube were made of tin, it would hold 1 cubic inch of water.

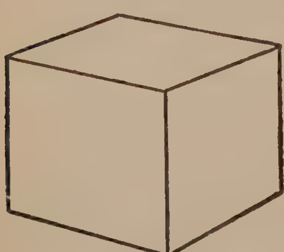


Figure 5

Now consider this same cube with divisions run through it as shown in figure 6, cutting the edges at their middle points. These divisions make eight smaller cubes, each having a length, width and height of $\frac{1}{2}$ of an inch. What is the volume of each of the smaller cubes? Their volume must be, of course, $\frac{1}{8}$ of a cubic inch.

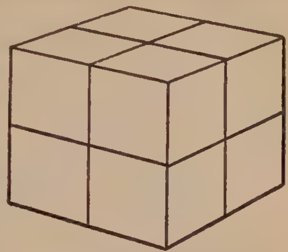


Figure 6

Now consider the object shown in figure 7. This object is 2 inches wide or thick, 3 inches long and 4 inches high or deep and has square corners. Its sides are rectangles. Such an object is

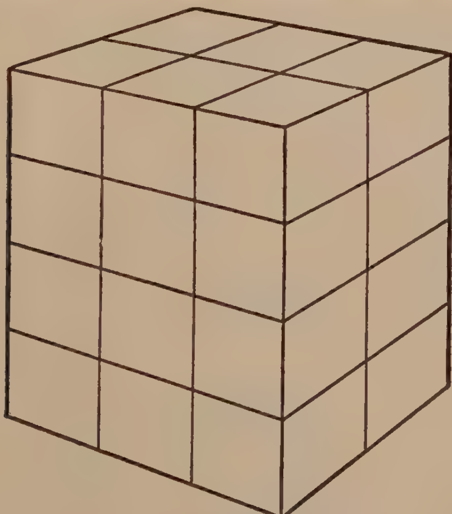


Figure 7

called a *prism*. A cube is a prism, with all its sides equal. We see that it is divided into 1-inch cubes. The area of the bottom of the object = 2 × 3 square inches = 6 square inches. So there must be 6 cubes on the bottom layer. And since the object is 4 inches high, there are 4 layers of cubes. Therefore,

there must be 4×6 cubes in the object, or 24 cubes. Therefore, the volume of the object is 24 cubic inches. From this we conclude that to find the volume of a prism, we multiply the area of the bottom or base by the height. This is also true of the little cubes in figure 6. We found the volume of the little cubes to be $\frac{1}{8}$ of a cubic inch. The area of one side is $\frac{1}{2} \times \frac{1}{2}$ square inches. The height is $\frac{1}{2}$ of an inch. $\frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} = \frac{1}{8}$. Hence,

volume of any prism = area of base × height.

It makes no difference which surface of a prism we consider as the base.

EXAMPLE: *What is the volume of a prism* $\frac{3}{4}'' \times 4\frac{1}{2}'' \times 5''$?

$$\tfrac{3}{4} \times 4\tfrac{1}{2} \times 5 = \tfrac{3}{4} \times \tfrac{9}{2} \times 5 = \tfrac{135}{8} = 16.875.$$

Answer: 16.875 cubic inches.

63. How many cubic inches are contained in a tank $1'\ 6''$ long × $1'$ wide × $6''$ deep?

A gallon contains 231 cubic inches.

A *cubic foot* is a volume equal to the volume of a prism all of whose edges are 1 foot long.

64. How many cubic inches in 1 cubic foot?

65. How many gallons would be contained in a prism $2'' \times 7'' \times 11''$?

66. How many gallons in a cubic foot?

67. How many gallons of size will be required to fill a size box whose inside dimensions are as follows: length, $5\frac{1}{2}$ ft.; width, $2\frac{1}{2}$ ft.; and depth, $10\frac{1}{2}$ in.?

68. The size boxes on slashers are generally kept $\frac{1}{2}$ full. How many gallons of size will be required to fill 9 size boxes $\frac{1}{2}$ full, the boxes being $66'' \times 28'' \times 12''$ deep (inside measure)?

69. How many cubic feet of a box car 34 ft. long, 8 ft. wide and 7 ft. high, will be left empty if 200 bales of cloth, each bale 36 in. high, 22 in. wide and 18 in. thick, are placed in it?

A cubic foot of water weighs $62\frac{1}{2}$ pounds.

70. A humidifier tank is 8 ft. long, 6 ft. wide and $3\frac{1}{2}$ ft. deep. How many pounds of water will it hold?

71. What is the capacity in cubic feet of a humidifier tank $16\frac{1}{2}$ feet long, 8 feet 9 inches wide and 2 feet 10 inches deep?

72. It is desired to make a water tank for a humidifier that will hold 1000 gallons. But on account of other things in the way, the tank can be but 77 inches long and 55 inches wide. What will be the required depth?

Areas and Volumes of Cylinders

Figure 8 represents a *cylinder*. As will be seen from figure 8, the ends (or bases) of a cylinder are circles of the same diameter. It is also evident that if the side of a cylinder were laid out flat, it would make a rectangle whose height would be the height of the cylinder and whose width would be the circumference of the circle. Since the circumference of a circle = 3.1416 × the diameter:

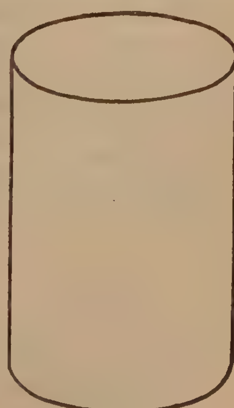


Figure 8

area of the side of a cylinder = circum. × height.

area of the side of a cylinder = 3.1416 × dia. × height.

73. How many square feet of tin would be required to make a slasher ventilator flue 15 inches in diameter and 14 feet long?

74. Find the number of square feet of copper that would be required to line the sides and bottom of a cylindrical size kettle 48×48 inches (inside dimensions)?

75. The heads of a slasher cylinder are made of cast iron and the drum part is sheet copper. How many square feet of sheet copper would be required to make a cylinder drum 5′ 6″ long whose heads are 9′ in diameter?

We have seen that the volume of a prism is equal to the area of its base times its height. We would expect the same to be true of a cylinder. Hence,

volume of a cylinder = .7854 × dia.^{2} × height.

Example: *What is the volume of a cylinder with a diameter of 2″ and a height of 10″?*

$.7854 \times 4 \times 10 = 31.416$. Answer: 31.416 cubic inches.

76. How many gallons of size will be required to fill a cylindrical size kettle 36″ in dia. × 36″ high?

77. How many pounds of starch will be needed to fill a 48″ × 48″ (cylindrical) kettle with cooked size, if one gallon of size contains 12 ounces of starch?

78. How many gallons of size will fill a circular storage kettle 6 ft. 5 in. in diameter and 6 ft. deep?

CHAPTER XVIII

SQUARE ROOT

SQUARE ROOTS OF PERFECT SQUARES

$2 \times 2 = 4$; $3 \times 3 = 9$; $4 \times 4 = 16$. The *square root* of 4 is 2; the square root of 9 is 3; the square root of 16 is 4. That is, the square root of a given number is a number which when multiplied by itself will produce the given number. Many necessary textile calculations involve square root. The sign ($\sqrt{\quad}$) means "the square root of." Thus, $\sqrt{4} = 2$; $\sqrt{9} = 3$; $\sqrt{16} = 4$.

PROBLEMS. *Find the value of:*

1. $\sqrt{25}$.
2. $\sqrt{36}$.
3. $\sqrt{49}$.
4. $\sqrt{64}$.
5. $\sqrt{81}$.
6. $\sqrt{100}$.
7. $\sqrt{121}$.
8. $\sqrt{144}$.

Experiments and tests have shown that for ordinary warp yarn the number of twists per inch should be $4.75 \times$ square root of the number of the yarn. For ordinary filling the twists per inch should be $3.25 \times$ square root of the number of the yarn. For roving the twists per inch are usually equal to $1.2 \times$ square root of the number of the roving.

Find the proper twists per inch of:

9. Number 9 filling.
10. Number 16 warp.
11. Number 25 warp.
12. Number 25 filling.
13. Number 4 roving.
14. Number 1 roving.

EXAMPLE: *Find the square root of* $2\frac{1}{4}$.

$2\frac{1}{4}=\frac{9}{4}$. $\therefore \sqrt{2\frac{1}{4}}=\sqrt{\frac{9}{4}}$. $\frac{9}{4}=\frac{3}{2}\times\frac{3}{2}$. $\therefore \sqrt{\frac{9}{4}}=\frac{3}{2}=1\frac{1}{2}$. $\therefore \sqrt{2\frac{1}{4}}=1\frac{1}{2}$.

Find the value of:

15. $\sqrt{1\frac{7}{9}}$. **17.** $\sqrt{1}$. **19.** $\sqrt{\frac{4}{9}}$. **21.** $\sqrt{\frac{1}{4}}$.

16. $\sqrt{1\frac{9}{16}}$. **18.** $\sqrt{\frac{9}{16}}$. **20.** $\sqrt{\frac{9}{25}}$. **22.** $\sqrt{\frac{1}{16}}$.

EXAMPLE: *Find the value of* $\sqrt{.04}$.

$\sqrt{.04} = \sqrt{.2 \times .2} = .2$. Or looking at the problem another way, $\sqrt{.04} = \sqrt{\frac{4}{100}} = \sqrt{\frac{2}{10} \times \frac{2}{10}} = \frac{2}{10} = .2$.

Find the value of:

23. $\sqrt{.01}$. **24.** $\sqrt{.09}$. **25.** $\sqrt{.16}$.

26. $\sqrt{.81}$. **27.** $\sqrt{1.00}$.

By studying your answers to the preceding problems answer the following:

28. Is the square root of a given number that is greater than one, greater or less than the given number?

29. Is the square root of a given number that is less than one, greater or less than the given number?

30. Prove that the square root of a fraction equals the square root of the numerator divided by the square root of the denominator.

Square Root by Factoring. Consider the number 36. $\sqrt{36}=6$. We also see that $\sqrt{36}=\sqrt{4\times9}=\sqrt{4}\times\sqrt{9}=2\times3=6$. That is, the *square root of a product is equal to the product of the square roots of the factors.*

$$\begin{array}{r} 2\underline{)36} \\ 2\underline{)18} \\ 3\underline{)9} \\ 3 \end{array}$$

Now let us factor 36 into its prime factors. The prime factors are two 2's and two 3's. The prime factors of 6 are one 2 and one 3. That is, the square root of a given number contains as factors half the number of each of the given number's prime factors.

$$\begin{array}{r} 2\,\underline{)144} \\ 2\,\underline{)72} \\ 2\,\underline{)36} \\ 2\,\underline{)18} \\ 3\,\underline{)9} \\ 3 \end{array}$$

Now consider the number 144. The prime factors of 144 are four 2's and two 3's. Therefore, $\sqrt{144}$ must contain as factors two 2's and one 3. That is, $\sqrt{144} = 2 \times 2 \times 3 = 12$.

By factoring find the square roots of:

31. 225. **32.** 256. **33.** 441. **34.** 1225. **35.** 11,025.

The preceding problems might have been solved by the following method: Suppose we wish to find the square root of 2209.

$22'\,09$

Set down the number and starting at the right and moving toward the left, separate it into *periods* of two digits each.

$\overline{22'\,09}$

Cover the number with a bar.

$$\begin{array}{r} 4 \\ \overline{22'\,09} \end{array}$$

Find the largest square root in the first period and set it over the first period. The largest square root contained in 22 is 4. Thus, 4 is the first digit of the square root.

$$\begin{array}{r} 4 \\ \overline{22'\,09} \\ 16 \\ \overline{)\;6\;\,09} \end{array}$$

Square the 4 which gives 16 and set the 16 under the 22. Subtract the 16 from the 22. Set the difference under a division bar and bring down the 09.

$$\begin{array}{r} 4 \\ \overline{22'\,09} \\ 16 \\ 8\;\overline{)\;6\;\,09} \end{array}$$

Double the 4 which makes 8. Set the 8 two spaces to the left of the division bar.

```
     4 7
    22′09
    16
87) 6 09
```

Divide the 8 into 60, the first two digits of 609. It goes 7 times. Put the 7 after the 4 and the 8.

```
     4 7
    22 09
    16
87) 6 09
    6 09
       0
```

Multiply the 87 by the 7 and set the product under the 609. $87 \times 7 = 609$.

Draw a bar and subtract. The remainder is 0. Hence, the $\sqrt{2209} = 47$. Proof: $47 \times 47 = 2209$.

Square Root of Any Number

All of our preceding discussion has considered only *perfect squares*, that is, numbers whose square roots can be found exactly. Now suppose we wish to find the square root of 924.157.

```
      3   0.
      9′24. 15′7
      9
  60)0 24
       00
       24 15
```

We separate the number into periods starting at the decimal point and moving both ways and then proceed as before. Six goes into 02 0 times. Multiply the 60 by the 0. Set down the product, 00; subtract and bring down the next period.

```
       3   0. 3
       9′24. 15′7
       9
   60)0 24
        00
 603)   24 15
        18 09
         6 067
```

Double the part of the square root already obtained. This gives 60. Divide the 60 into 241. It goes 4 times. But if we try to multiply 604 by 4 we obtain 2416 which will not subtract from 2415. Therefore, we put down 3. Put down 1809, the product of 3×603. Subtract and bring down the next period.

```
       3  0. 3 9
       9′24.15′7
       9
   60)0 24
        00
  603)  24 15
        18 09
 6069)     6 06 7
           5 46 2
             60 5
```

Double the part of the square root already found. This gives 606. Divide 606 into 6067, which gives 10. The largest number, however, that we put down is 9. Set down the 9 as before. $9 \times 6069 = 54{,}621$.

Therefore, the approximate square root of 924.157 is 30.39.

Proof: $30.39 \times 30.39 = 923.5521$.

If we wish to obtain the approximate square root quite accurately we can annex periods of 0's to the number. Suppose we wish to obtain the $\sqrt{5}$ carried to 3 decimal places:

```
     2. 2  3  6
     5.00′00′00
     4
 42)1 00
       84
443) 16 00
     13 29
4466) 2 71 00
      2 67 96
         3 04
```

$\therefore \sqrt{5} = 2.236$.

Proof: $2.236 \times 2.236 = 4.9999696$.

By one of the preceding methods find the twists per inch required by the following numbers of yarn and roving. Use the shortest method suitable for each problem. Carry approximate square roots to four decimal places and twists per inch to two decimal places.

36. .6 roving.

37. 6 roving.

38. .55 roving.

39. 55 warp yarn.

40. 10.5 filling yarn.

41. 30.56 filling yarn.

SQUARE ROOT TABLES

Number	Square Root	Number	Square Root	Number	Square Root
.25	.500	.68	.825	1.22	1.105
.26	.510	.69	.831	1.24	1.114
.27	.520	.70	.837	1.26	1.122
.28	.529	.71	.843	1.28	1.131
.29	.539	.72	.849	1.30	1.140
.30	.548	.73	.854	1.32	1.149
.31	.557	.74	.860	1.34	1.158
.32	.566	.75	.866	1.36	1.166
.33	.574	.76	.872	1.38	1.175
.34	.583	.77	.874	1.40	1.183
.35	.592	.78	.883	1.42	1.192
.36	.600	.79	.889	1.44	1.200
.37	.608	.80	.894	1.46	1.208
.38	.616	.81	.900	1.48	1.217
.39	.624	.82	.906	1.50	1.225
.40	.632	.83	.911	1.52	1.233
.41	.640	.84	.917	1.54	1.241
.42	.648	.85	.922	1.56	1.249
.43	.655	.86	.927	1.58	1.257
.44	.663	.87	.933	1.60	1.265
.45	.671	.88	.938	1.62	1.273
.46	.678	.89	.943	1.64	1.281
.47	.686	.90	.949	1.66	1.288
.48	.693	.91	.954	1.68	1.296
.49	.700	.92	.959	1.70	1.304
.50	.707	.93	.964	1.72	1.311
.51	.714	.94	.970	1.74	1.319
.52	.721	.95	.975	1.76	1.327
.53	.728	.96	.980	1.78	1.334
.54	.735	.97	.985	1.80	1.342
.55	.742	.98	.990	1.82	1.349
.56	.748	.99	.995	1.84	1.356
.57	.755	1.00	1.000	1.86	1.364
.58	.762	1.02	1.010	1.88	1.371
.59	.768	1.04	1.020	1.90	1.378
.60	.775	1.06	1.030	1.92	1.386
.61	.781	1.08	1.039	1.94	1.393
.62	.787	1.10	1.049	1.96	1.400
.63	.794	1.12	1.058	1.98	1.407
.64	.800	1.14	1.068	2.00	1.414
.65	.806	1.16	1.077	2.02	1.421
.66	.812	1.18	1.086	2.04	1.428
.67	.819	1.20	1.095	2.06	1.435

Number	Square Root	Number	Square Root	Number	Square Root
2.08	1.442	3.00	1.732	7.60	2.757
2.10	1.449	3.10	1.761	7.70	2.775
2.12	1.456	3.20	1.789	7.80	2.793
2.14	1.463	3.30	1.817	7.90	2.811
2.16	1.470	3.40	1.844	8.00	2.828
2.18	1.476	3.50	1.871	8.10	2.846
2.20	1.483	3.60	1.897	8.20	2.864
2.22	1.490	3.70	1.924	8.30	2.881
2.24	1.497	3.80	1.949	8.40	2.898
2.26	1.503	3.90	1.975	8.50	2.915
2.28	1.510	4.00	2.000	8.60	2.933
2.30	1.517	4.10	2.025	8.70	2.950
2.32	1.523	4.20	2.049	8.80	2.966
2.34	1.530	4.30	2.074	8.90	2.983
2.36	1.536	4.40	2.098	9.00	3.000
2.38	1.543	4.50	2.121	9.10	3.017
2.40	1.549	4.60	2.145	9.20	3.033
2.42	1.556	4.70	2.168	9.30	3.050
2.44	1.562	4.80	2.191	9.40	3.066
2.46	1.568	4.90	2.214	9.50	3.082
2.48	1.575	5.00	2.236	9.60	3.098
2.50	1.581	5.10	2.258	9.70	3.114
2.52	1.587	5.20	2.280	9.80	3.130
2.54	1.594	5.30	2.302	9.90	3.146
2.56	1.600	5.40	2.324	10.00	3.162
2.58	1.606	5.50	2.345	11.00	3.3166
2.60	1.612	5.60	2.366	12.00	3.4641
2.62	1.619	5.70	2.387	13.00	3.6056
2.64	1.625	5.80	2.408	14.00	3.7417
2.66	1.631	5.90	2.420	15.00	3.8730
2.68	1.637	6.00	2.449	16.00	4.0000
2.70	1.643	6.10	2.470	17.00	4.1231
2.72	1.649	6.20	2.490	18.00	4.2426
2.74	1.655	6.30	2.510	19.00	4.3589
2.76	1.661	6.40	2.530	20.00	4.4721
2.78	1.667	6.50	2.550	21.00	4.5826
2.80	1.673	6.60	2.569	22.00	4.6904
2.82	1.679	6.70	2.588	23.00	4.7958
2.84	1.685	6.80	2.606	24.00	4.8990
2.86	1.691	6.90	2.027	25.00	5.0000
2.88	1.697	7.00	2.646	26.00	5.0990
2.90	1.703	7.10	2.665	27.00	5.1962
2.92	1.709	7.20	2.683	28.00	5.2915
2.94	1.715	7.30	2.702	29.00	5.3852
2.96	1.721	7.40	2.720	30.00	5.4772
2.98	1.726	7.50	2.739	31.00	5.5678

Number	Square Root	Number	Square Root	Number	Square Root
32	5.6569	72	8.4853	112	10.5830
33	5.7446	73	8.5440	113	10.6301
34	5.8310	74	8.6023	114	10.6771
35	5.9161	75	8.6603	115	10.7238
36	6.0000	76	8.7178	116	10.7703
37	6.0828	77	8.7750	117	10.8167
38	6.1644	78	8.8318	118	10.8628
39	6.2450	79	8.8882	119	10.9087
40	6.3246	80	8.9443	120	19.0545
41	6.4031	81	9.0000	121	11.0000
42	6.4807	82	9.0554	122	11.0454
43	6.5574	83	9.1104	123	11.0905
44	6.6332	84	9.1652	124	11.1355
45	6.7082	85	9.2195	125	11.1803
46	6.7823	86	9.2736	126	11.2250
47	6.8557	87	9.3274	127	11.2694
48	6.9282	88	9.3808	128	11.3137
49	7.0000	89	9.4340	129	11.3578
50	7.0711	90	9.4868	130	11.4018
51	7.1414	91	9.5394	131	11.4455
52	7.2111	92	9.5917	132	11.4891
53	7.2801	93	9.6437	133	11.5326
54	7.3485	94	9.6954	134	11.5758
55	7.4162	95	9.7468	135	11.6190
56	7.4833	96	9.7980	136	11.6619
57	7.5498	97	9.8489	137	11.7047
58	7.6158	98	9.8995	138	11.7473
59	7.6811	99	9.9499	139	11.7898
60	7.7460	100	10.0000	140	11.8322
61	7.8102	101	10.0499	141	11.8743
62	7.8740	102	10.0995	142	11.9164
63	7.9373	103	10.1489	143	11.9583
64	8.0000	104	10.1980	144	12.0000
65	8.0623	105	10.2470	145	12.0416
66	8.1240	106	10.2956	146	12.0830
67	8.1854	107	10.3441	147	12.1244
68	8.2462	108	10.3923	148	12.1655
69	8.3066	109	10.4403	149	12.2066
70	8.3666	110	10.4881	150	12.2474
71	8.4261	111	10.5357		

Interpolation of Tables. Suppose we wish to find from the table the square root of 40.76. The table gives the square root of 40 and the square root of 41. From these two square roots, we can roughly approxi-

mate the square root of 40.76. This is called *interpolation.* We reason as follows:

$$\begin{array}{rrrr} 41.00 & 40.76 & \sqrt{41} & \doteq 6.4031 \\ -\underline{40.00} & -\underline{40.00} & -\underline{\sqrt{40}} & = \underline{6.3246} \\ 1.00 & .76 & & .0785 \end{array}$$

Since the difference between 40.76 and 40.00 is .76 of the difference between 41.00 and 40.00, the difference between $\sqrt{40.76}$ and $\sqrt{40.00}$ will be .76 of the difference between $\sqrt{41.00}$ and $\sqrt{40.00}$.

$$.76 \times .0785 = .0597. \quad \begin{array}{r} 6.3246 \\ \underline{.0597} \\ 6.3843 \end{array} \quad \therefore \text{ Interpolated } \sqrt{40.76} = 6.3843.$$

This reasoning, however, is not mathematically true and will give only an approximately correct result when the two numbers between which we interpolate are close together, such as 40 and 41.

Interpolate the square roots of the following numbers:

42. 16.25. **43.** 18.50. **44.** 20.75.

45. 31.83. **46.** 42.93.

Multiplying or Dividing by 10. Suppose we wish to find the square root of .15:

$.15 = \frac{15}{100}$. $\therefore \sqrt{.15} = \sqrt{\frac{15}{100}} = \frac{\sqrt{15}}{\sqrt{100}} = \frac{\sqrt{15}}{10}$. The table shows that $\sqrt{15} = 3.8730$. $\therefore \frac{\sqrt{15}}{10} = .38730$. $\therefore \sqrt{.15} = .38730$. Suppose we wish to find the square root of 180. $\sqrt{180} = \sqrt{100 \times 1.8} = 10 \times \sqrt{1.8}$. The table shows that $\sqrt{1.8} = 1.342$. $\therefore \sqrt{180} = 13.42$.

Find the square root of:

47. .20. **48.** .18. **49.** 156. **50.** 1.43.

CHAPTER XIX

RATIO AND PROPORTION

Proportion Considered as a Fractional Equation

Suppose we have a sample of cloth 3″ square which weighs 7 grains and we wish to find the weight of a 1-yard length of this cloth 40″ wide. We can reason this way: The square inches of the 3″ square sample must be contained in the square inches of the 1-yard length just as many times as the grains of the sample are contained in the grains of the 1-yard length. That is to say, the square inches of the 1-yard length divided by the square inches of the sample = the grains of the 1-yard length divided by the grains of the sample. Putting this statement in the form of fractions we have:

$$(a)\quad \frac{\text{square inches of 1-yard length}}{\text{square inches of sample}} = \frac{\text{grains of 1-yard length}}{\text{grains of sample}}.$$

$$\text{square inches of 1-yard length} = 36 \times 40 = 1440$$
$$\text{square inches of sample} = 3 \times 3 = 9$$
$$\text{grains of sample} = 7.$$

Substituting these numbers in equation (a) we obtain the following:

(b) $\frac{1440}{9} = \frac{\text{grains of 1-yard length}}{7}$. We remember from chapter XVI that we can multiply and divide and add to and subtract from both sides of an equation with the same number and still keep the equation true.

Multiplying both sides by 7 and then canceling we obtain the following equation:

$$(c)\quad \frac{\overset{160}{\cancel{1440}} \times 7}{\cancel{9}} = \frac{7 \times \text{grains of 1-yard length}}{\cancel{7}}.$$

This simplified gives us:

(d) 1120 = grains of 1-yard length. ∴ Weight of 1 yard = 1120 grains.

Ratio and Proportion. Equations (a), (b) and (c) are *proportions.* Both sides of equations (a), (b) and (c) are *ratios.* A ratio, therefore, is a fraction. A proportion is, therefore, an equation showing that one ratio is equal to another ratio. Looking at equations (a) and (b) we see that the ratio on the left side compares, or expresses the relationship of, the *area* of 1 yard of cloth to the *area* of a 3″ square piece of the same kind of cloth; while the ratio on the right compares, or expresses the relationship of, the *weight* of one yard of the same cloth to the *weight* of a 3″ square piece of the same cloth. And the proportion (or equation) expresses the fact that the relation of the *area* of the yard to the *area* of the 3″ square is exactly the same as the relation of the *weight* of the yard to the *weight* of the 3″ square.

Solving a problem, therefore, by *ratio and proportion* consists, first, in reasoning out in your mind the relationships existing between the quantities given and asked for in the problem; second, in setting these relationships on paper in the form of a proportion; third, in reducing and simplifying the proportion.

Short Cuts in Simplifying Proportions. Suppose we have the following proportion:

$$(1)\ \frac{A \times B}{C \times D} = \frac{a \times b}{c \times d}.$$

Let us see into how many forms we can rearrange this equation without changing its truth. Multiplying both sides by $C \times D \times c \times d$ we obtain:

$$\frac{A \times B \times C \times D \times c \times d}{C \times D} = \frac{a \times b \times C \times D \times c \times d}{c \times d}.$$

Canceling we obtain:

$$(2)\ A \times B \times c \times d = a \times b \times C \times D.$$

Here we see that the product of the left numerator and right denominator always equals the product of the right numerator and left denominator.

Dividing both sides of (2) by $A \times B \times a \times b$ we obtain:

$$\frac{A \times B \times c \times d}{A \times B \times a \times b} = \frac{a \times b \times C \times D}{A \times B \times a \times b}.$$

Canceling we obtain:

$$\frac{c \times d}{a \times b} = \frac{C \times D}{A \times B}.$$

Reversing sides we have:

$$(3) \quad \frac{C \times D}{A \times B} = \frac{c \times d}{a \times b}.$$

Here we see that the original proportion can be inverted and still be true.

Multiplying both sides of (1) by $C \times D$ we obtain:

$$\frac{A \times B \times C \times D}{C \times D} = \frac{a \times b \times C \times D}{c \times d}.$$

Canceling we obtain:

$$(4) \quad A \times B = \frac{a \times b \times C \times D}{c \times d}.$$

Here we see that the left numerator equals the product of the right numerator and the left denominator divided by the right denominator.

PROBLEMS. *By means similar to those used in working out equations* (2), (3) *and* (4) *prove that:*

1. $$(5) \quad C \times D = \frac{c \times d \times A \times B}{a \times b}.$$

2. $$(6) \quad a \times b = \frac{A \times B \times c \times d}{C \times D}.$$

3. $$(7) \quad c \times d = \frac{C \times D \times a \times b}{A \times B}.$$

4. $$(8) \quad A = \frac{a \times b \times C \times D}{B \times c \times d}.$$

5. $$(9) \quad B = \frac{a \times b \times C \times D}{A \times c \times d}.$$

6. $$(10) \quad a = \frac{A \times B \times c \times d}{b \times C \times D}.$$

7. $$(11) \quad b = \frac{A \times B \times c \times d}{a \times C \times D}.$$

8. (12) $C = \dfrac{c \times d \times A \times B}{D \times a \times b}.$

9. (13) $D = \dfrac{c \times d \times A \times B}{C \times a \times b}.$

10. (14) $c = \dfrac{C \times D \times a \times b}{d \times A \times B}.$

11. (15) $d = \dfrac{C \times D \times a \times b}{c \times A \times B}.$

EXAMPLE: *If* 49 *cards produced* 40,425 *lbs. of* 60-*grain sliver in* 1 *week, how many pounds of the same sliver will* 57 *cards produce in a week?*

We see at once that the ratio of 49 cards to 57 cards must be the same as the ratio of 40,425 lbs. to the pounds that 57 cards will produce.

Let p stand for the pounds that 57 cards will produce, $\therefore \dfrac{49}{57} = \dfrac{40{,}425}{p}.$ In this equation we see that p corresponds in position to $c \times d$ in equation (1). Hence, from the short cut shown by equation (7) in problem 3 preceding we see that $p = \dfrac{57 \times 40{,}425}{49} = 47{,}025.$ Answer: 47,025 lbs.

12. If 24 drawing frame deliveries produce 5232 lbs. of 65-grain sliver in one day, how much will 40 deliveries, delivering at the same rate, produce of the same sliver in one day?

13. 304 speeder spindles delivered 2772.48 hanks of number 3.00 roving in 10 hours, how many hanks of the same roving will 256 speeder spindles deliver in 10 hours?

14. In 75 hours 1360 spindles have produced 5049 lbs. of number 16 warp yarn for a certain order. How much should these same spindles produce at this rate in the next 35 hours?

15. If 1372 spindles are required to make filling for 98 looms, how many spindles will be required to make filling for 420 looms on the same style of cloth?

Proportion Considered as a Method of Reasoning

Meaning of Direct Proportion. Let us again consider the problem at the beginning of this chapter: If a sample of cloth 3″ square weighs 7 grains, what will be the weight of the 1-yard length? We see at once that doubling the square inches in the 1-yard length would double the grains in the 1-yard length. In other words, the square inches are *directly proportional* to the grains. This meaning of *direct proportion* can also be illustrated from equation (a); for we see that since the ratios are equal, if the denominators remain the same, any increase in the numerator on one side must bring about an increase in the numerator of the other side. Now this brings us to the real meaning of ratio and proportion. Ratio and proportion is more than merely an equation between two fractions. It is a *method of reasoning* or of *seeing mathematical relationships* that will quicken your insight into all calculations.

Elements of a Proportion. In the few ratio and proportion problems which we have studied thus far there has been *one unknown* quantity which you were required to find from the *three known* quantities which were given in each problem. Hence, in every proportion there are four quantities, which we may call the *elements* of the proportion.

How to Reason. Let us again consider the problem at the beginning of this chapter. There are four elements of the problem: two of the elements are areas; two are weights. We have seen that a ratio expresses

the relationship between two elements of the same kind; that is, a ratio compares area with area, weight with weight, length of time with length of time, etc. Very well, put the first element that you see down on paper. In this problem it is "3″ square" or 9 square inches.

9

$$\frac{9}{\quad} = \frac{\quad}{\quad}$$

Put the nine down on paper.

Draw a fraction bar under (or over) the 9. Draw an equal sign and another fraction bar after the equal sign.

$$\frac{9}{36 \times 40} = \frac{\quad}{\quad}$$

The 9 represents an area. Pick out the other area element and put it down so as to form a ratio between the two area elements.

Then pick out the remaining known element. In this case it is 7 grains. Then reason out whether or not the 7 grains is directly proportional to the area of the sample. That is, would increasing the area of the sample increase the weight of the sample at the same rate? It would. Therefore, the 7 and the 9 are directly proportional.

$$\frac{9}{36 \times 40} = \frac{7}{\quad}$$

Therefore, put the 7 on the right side of the proportion in line with the 9.

The unknown element must go in the remaining blank space forming a ratio between itself and the element on the opposite side of the fraction bar from itself. Let u stand for the unknown element.

$$\frac{9}{36 \times 40} = \frac{7}{u}$$

$$u = \frac{7 \times \overset{4}{\cancel{36}} \times 40}{\cancel{9}}$$

$$u = 1120.$$

Put the u in its proper place.

Solve for u. That is, find the value of u by one of the short cuts.

Now since 7 stands for grains and forms a ratio with u, u *must* stand for grains. Therefore, a yard of this cloth weighs 1120 grains. Be sure you understand the last bit of reasoning.

Meaning of Inverse Proportions. Let us consider this problem: A certain plain cloth $41\frac{1}{2}''$ wide contains 5 yds. to a pound. If this cloth is made $45''$ wide, how many yards will there be to the pound?

$41\frac{1}{2}$

As a starter we set down the first element we come to, which is $41\frac{1}{2}$, which stands for width.

$\frac{41\frac{1}{2}}{45} = \underline{\qquad\qquad}$

Pick out the other width element and form a ratio between it and the first width element.

Then pick out the remaining known element. It is "5 yards to the pound." Now then, is the number of yards to a pound of cloth directly proportional to the width of the cloth? No, because the *greater* the width of the cloth the heavier a yard will be, and, hence, the *fewer* the yards to the pound. For instance, if the width of the cloth were *doubled* the yards to the pound would be *halved*. Therefore, we say that width and yards to the pound are *inversely proportional*. That is, increasing the width from $41\frac{1}{2}''$ to $45''$ makes the yards per pound less than 5. u, the unknown element, represents the "yards to the pound" of the $45''$ width and must form a ratio with 5. But u, as we have just reasoned, must be less than 5. Since the ratio on the right must equal the ratio on the left, and since the left numerator is less than the left denominator, the right numerator must be less than the right denominator. Hence, u must be the numerator and 5 the denominator of the right side.

$\frac{41\frac{1}{2}}{45} = \frac{u}{5}$

Put u and 5 in their proper places.

$u = \frac{5 \times 41\frac{1}{2}}{45}$

Solve for u, using one of the short cuts.

$u = 4.06$

This must mean that the $45''$ width of cloth contains 4.06 yards to a pound.

PROBLEMS: *Some of the following problems involve inverse proportion. The others involve direct proportion. You must first reason out whether the problem involves direct or inverse proportion.*

16. A picker is delivering 48-yard rolls of 13-oz. lap. We wish to change to 12-oz. lap. How many yards shall we put in the rolls of lap in order that the rolls of 12-oz. lap shall weigh the same as the rolls of 13-oz. lap?

17. The spinning frames making number 40 filling produced 12,560 lbs. in one week, which was 88% production. How many pounds of this number per week must these frames produce to obtain 90% production?

18. During one week 960 jack frame spindles produced 33,264 hanks of number 10 roving which was 92.8% production. The next week these same spindles produced 33,148 hanks of number 10 roving. What was their percent of production for this week?

19. A girl spinner running 8 sides makes $11.88 in $5\frac{1}{2}$ days. How much will she make when she can run 10 sides?

20. 12,000 spindles produced in 90 hours half of the filling yarn required for a certain order. How long will it require 9000 spindles to produce the remaining half of the order?

21. If 20 looms will weave 4880 yards of cloth in a week, how many yards will 76 looms weave?

22. If 24 looms will weave the cloth for a certain order in 72 hours, how many hours will be required for 36 looms to weave the same amount and kind of cloth for another order?

23. A weaver makes 18 dollars a week running 20 looms, how much will he make when he becomes efficient enough to run 24 looms?

24. If weavers are paid 15 cents per cut for weaving cloth containing 48 picks of filling per inch, what would be the price paid per cut for cloth containing 60 picks of filling per inch?

25. If a loom will make 51 yards of cloth, 48 picks to the inch, in 10 hours, how many yards of cloth, 60 picks per inch, will it make in 10 hours.

26. A loom on a test ran $9\frac{1}{2}$ hours and wove $43\frac{7}{10}$ yards, how many yards will it weave in 55 hours?

27. A certain weaver on a certain style of cloth runs 20 looms and earns on the average $24.50 per week of 55 hours. How long would it take him to earn this same amount if he could run 22 looms?

28. A certain style of cloth 30″ wide is being made with 1440 warp ends; it is desired to make this cloth 36 inches wide with the same amount of warp ends per inch in the cloth. How many warp ends will be required?

29. A drill 30″ wide and containing 2.50 yards per pound is being made, but it is desired to make this cloth 39″ wide, changing the width and weight only. What will be the yards per pound?

30. If a sample piece of sheeting 4 inches square weighs $17\frac{1}{4}$ grains, what width must the cloth be made for 5 yards to weigh one pound?

Proportions of More than Four Elements. Suppose we wish to solve the following problem by proportion: A 58-yard cut of cloth 30 inches wide weighs 12 lbs. What will be the weight of a 60-yard cut of this same cloth made 36 inches wide?

Let w stand for the weight of a 60-yard cut of cloth 36″ wide. We reason that w is directly proportional to the length of the cut.

$$\frac{w}{\ } = \frac{60}{\ }$$

Therefore, set w down as one numerator and 60 as the other numerator, since they are directly proportional. Is w directly proportional to any other element? Yes, it is directly proportional to the width of the cloth.

$$\frac{w}{\ } = \frac{60 \times 36}{\ }$$

Set 36 down as a factor beside 60.

$$\frac{w}{12} = \frac{60 \times 36}{\ }$$

Put 12 under w, since 12 and w are the same kind of elements.

$$\frac{w}{12} = \frac{60 \times 36}{58 \times 30}$$

And since 12 is directly proportional to 58×30, for the same reason that w is directly proportional to 60×36, set 58×30 down in line with 12.

$$w = \frac{60 \times 36 \times 12}{58 \times 30}$$

Solve for w.

$$w = 14.9$$

Therefore, a 58-yard cut 36″ wide will weigh 14.9 lbs.

31. If 15 cents is paid for weaving a 60-yard cut of sheeting containing 48 picks per inch, how much will be paid for weaving a 62-yard cut of sheeting containing 56 picks per inch at the same rate per pick?

32. Weavers are being paid $18\frac{2}{5}$¢ per cut for weaving drills, 46 picks per inch, and are running 20 looms. It is desired to change to sateens, 56 picks per inch, giving each weaver 16 looms. How much must be paid per cut so that the weavers may make the same wages per week?

33. An order is received for 142,560 lbs. of a certain number of yarn. In 12 days 4320 spindles produce

15,552 lbs. of the order. How many spindles must be put on this yarn to produce the balance of the order in 90 days?

34. If a 65-yard cut of cloth 36″ wide weighs 25 lbs., what should be the weight of a $63\frac{1}{2}$-yard cut of the same cloth made $31\frac{1}{2}$″ wide?

CHAPTER XX

PULLEYS, GEARS, BELTS AND LEVERS

In figure 1, A and B are two pulleys connected by a belt. Let us suppose that shaft a to which A is fastened is driven by the engine. That is, a is the drive shaft. Hence, pulley A is the *driver* pulley and pulley B is the *driven* pulley. On a machine the *driven* pulley which is driven by a pulley on a shaft is often referred to as the *drive* pulley or the *driving* pulley. But in this book we shall always refer to a pulley which drives another pulley as a *driver* pulley and to a pulley driven by another pulley as a *driven* pulley.

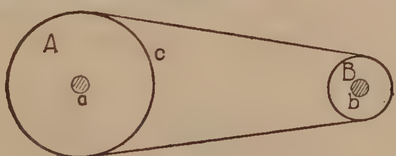


Figure 1

Suppose that pulley A is 10 feet in circumference and pulley B is 5 feet in circumference. Suppose that A makes 1 revolution or 1 complete turn. This means that since the belt is tight, 10 feet of the belt will have passed over B, which in turn means that, since B is 5 feet in circumference, B will make 2 revolutions while A is making 1 revolution. We, therefore, see that when we consider two pulleys connected by a belt their revolutions are inversely proportional to their circumference. Hence, the following ratios and proportion:

$$(1)\quad \frac{\text{revolutions of } B}{\text{revolutions of } A} = \frac{\text{circumference of } A}{\text{circumference of } B}.$$

We remember that the circumference of any circle $= 3.1416 \times$ its diameter.

Substituting this expression into equation (1) we have:

$$\frac{\text{revolutions of } B}{\text{revolutions of } A} = \frac{3.1416 \times \text{dia. of } A}{3.1416 \times \text{dia. of } B}.$$ Canceling 3.1416 we have:

$$(2)\quad \frac{\text{revolutions of } B}{\text{revolutions of } A} = \frac{\text{dia. of } A}{\text{dia. of } B}.$$

Revolutions per Minute. When we say that a pulley is running at a high speed we mean that it makes a large number of revolutions in a given period of time. The usual period of time considered is 1 minute. Hence, we measure the speed of revolving objects such as pulleys, shafting and machine parts according to their *revolutions per minute.* The abbreviation for revolutions per minute is R.P.M. Thus, if a pulley makes 100 revolutions in 1 minute its speed is 100 R.P.M.

We can, therefore, rewrite equation (2) as follows:

$$(3)\quad \frac{\text{R.P.M. of } B}{\text{R.P.M. of } A} = \frac{\text{dia. of } A}{\text{dia. of } B}.$$

EXAMPLE: *If the diameter of* A *is* 30″ *and the diameter of* B *is* 10″ *and* A *makes* 150 *R.P.M., what is the speed of* B?

Substituting in equation (3) we have:

$$\frac{\text{R.P.M. of } B}{150} = \frac{30}{10}. \quad \therefore \text{R.P.M. of } B = \frac{30 \times 150}{10} = 450.$$

PROBLEMS:

1. If A is 16″ in diameter and B is 3″ in diameter, what must be the speed of A in order for B to make 750 R.P.M.?

2. (*a*) If the speed of A is 356 R.P.M. and the diameter of A is 28″, what must be the diameter of B in order for B to make 280 R.P.M.?

(*b*) If pulleys are made with diameters in full or half inches, what size shall we use in order to give B a speed as near as possible to the speed required in (*a*)?

Formulas. Equation (3) rearranged would give us the following equation:

(4) $\text{dia. of } A = \dfrac{\text{R.P.M. of } B \times \text{dia. of } B}{\text{R.P.M. of } A}$. Now whenever we know the conditions required on the right side of equation (4) we can always find the diameter of A necessary to produce these required conditions. Equation (4) can be called a *formula* for the diameter of A.

EXAMPLE: *If the diameter of* B *is* 8″ *and must make* 500 *R.P.M., and the speed of the shaft* a *is* 150 *R.P.M., what must be the diameter of* A?

Using formula (4): $\text{dia. of } A = \dfrac{500 \times 8}{150} = 26.67.$

Answer: A must be 26.67″ in diameter.

NOTE: The nearest size available would probably be $26\frac{1}{2}$″ or 27″.

3. Work out a formula for: (*a*) diameter of B; (*b*) R.P.M. of B.

Using the appropriate formulas, solve the following problems:

4. The pulley on a card is 20″ in diameter and must make 165 R.P.M. The overhead shaft makes 200 R.P.M. What must be the size of the overhead pulley?

5. The driven pulley on a certain spinning frame must make 1300 R.P.M. The overhead driver pulley

makes 400 R.P.M. and is 30″ in diameter. What must be the diameter of the driven pulley on the frame?

Surface Speed. Returning to figure 1, suppose pulley *A* makes 300 R.P.M., and is 10 feet in circumference. That is, the point *c* on the rim of the pulley travels 10 feet at every revolution of the pulley. Hence, in one minute it travels 300 × 10 ft. or 3000 ft. The *surface speed* of pulley *A* is, therefore, 3000 ft. per minute. Letting S.S. stand for surface speed we, therefore, have the following equation (or formula):

(5) S.S. of A = R.P.M. of A × cir. of A. Since the circumference of a circle = 3.1416 × the diameter of a circle, equation (5) may be written:

(6) S.S. of A = 3.1416 × dia. of A × R.P.M. of A. Dividing both sides of equation (6) by 3.1416 × dia. of A we have:

(7) $\text{R.P.M. of } A = \dfrac{\text{S.S. of } A}{3.1416 \times \text{dia. of } A}.$

Using the appropriate formula, solve the following problems:

6. What is the surface speed in feet per minute of the main engine flywheel 18 ft. in diameter which makes 80 R.P.M.?

7. What is the surface speed in inches per minute of a fly frame front roll $1\frac{3}{16}''$ in diameter and making 200 R.P.M.?

8. What must be the R.P.M. of a 9″ (diameter) picker calender roll to deliver 210 inches of lap per minute?

Pulley Trains

Figure 2 represents a train of four pulleys connected by belts. Pulleys *B* and *C* are fastened to the same

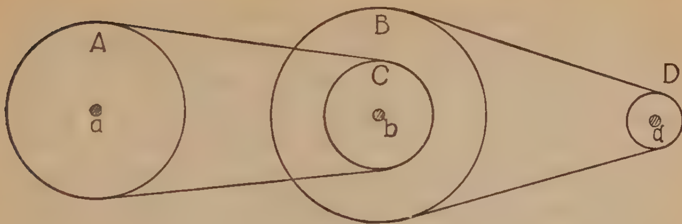


Figure 2

shaft. Considering pulleys A and B we see from equation (3) that:

$$(8)\ \frac{\text{R.P.M. of } B}{\text{R.P.M. of } A} = \frac{\text{dia. of } A}{\text{dia. of } B}.$$

Then considering pulleys C and D, from equation (3) we have:

$$(9)\ \frac{\text{R.P.M. of } D}{\text{R.P.M. of } C} = \frac{\text{dia. of } C}{\text{dia. of } D}.$$

Multiplying the left side of (8) by the left side of (9) and the right side of (8) by the right side of (9), we have:

$$(10)\ \frac{\text{R.P.M. of } B \times \text{R.P.M. of } D}{\text{R.P.M. of } A \times \text{R.P.M. of } C} = \frac{\text{dia. of } A \times \text{dia. of } C}{\text{dia. of } B \times \text{dia. of } D}.$$

But we know that the R.P.M. of B is the same as the R.P.M. of C because they are fastened to the same shaft. Therefore, we may cancel R.P.M. of B and R.P.M. of C out of the numerator and denominator of the left side of (10). Hence, (10) becomes:

$$(11)\ \frac{\text{R.P.M. of } D}{\text{R.P.M. of } A} = \frac{\text{dia. of } A \times \text{dia. of } C}{\text{dia. of } B \times \text{dia. of } D};\ \text{and, therefore:}$$

$$(12)\ \text{R.P.M. of } D = \frac{\text{R.P.M. of } A \times \text{dia. of } A \times \text{dia. of } C}{\text{dia. of } B \times \text{dia. of } D}.$$

It is obvious that regardless of which pulley is the driver or the driven pulley all of the equations from (1) on are true. In figure 2, the driver shaft might be b, making both B and C driver pulleys and A and D driven pulleys. Nevertheless, equations (11) and (12) would still be true. However, it is convenient in thinking about a pulley train to consider one of the pulleys

at the end of the train a driver and then the next pulley as a driven, the next as a driver, the next as a driven, and so on. Let us look at equation (11) considering pulley D as a driver. We see that:

(*a*) The ratio of the R.P.M. of the first *driver* pulley to the R.P.M. of the last *driven* pulley equals the product of the diameters of all the *driven* pulleys divided by the product of the diameters of all the *driver* pulleys. Or we can say:

(*b*) The R.P.M.'s of two pulleys are *inversely* proportional to the products of the diameters of the driver and driven pulleys.

If we consider D as a driven pulley then statements (*a*) and (*b*) would be reversed, but the proportions would remain the same. In any event do not try to remember rules. Get the "hang of the thing" and be sure that you can reason it out.

9. Prove that in any train of pulleys if the size of any driver pulley equals the size of any driven pulley, these two pulleys have no effect on the speed of the rest of the pulleys that come after them in the train. Refer to formula (12).

10. If the pulleys in figure 2 have the following diameters: A 20″, B 8″, C 24″ and D 6″, and A makes 480 R.P.M., what will be the speed of D?

11. If the main engine makes 80 R.P.M., and has an 18-ft. flywheel and drives a 6-ft. pulley on the main line shaft of the spinning room which in turn carries a 3-ft. pulley which is belted to a 30″ pulley on the jack shaft, how many R.P.M. does the jack shaft make?

12. Work out a formula for the diameter of C, figure 2, and then use it in solving this problem: The jack shaft under a weave room makes 250 R.P.M. and carries

a 36″ pulley which runs a 48″ pulley on the counter shaft under the looms on the floor above. The loom carries a 15″ pulley which must make 150 R.P.M. What must be the diameter of the driver pulley on the counter shaft?

13. The pulley on a card room motor is 10″ in diameter, makes 825 R.P.M., and drives a pulley on a line shaft which carries the pulleys that are to drive a line of cards. If the 20″ pulleys on the cards must make 165 R.P.M., and the driver pulley on the line shaft is 14″ in diameter, what must be the diameter of the driven pulley on the line shaft?

Answer the following questions by studying equation (12) *and without doing any calculating:*

14. Is the R.P.M. of D directly or inversely proportional to the diameter of A? Why?

15. Is the R.P.M. of D directly or inversely proportional to the diameter of C? Why?

16. Is the R.P.M. of D directly or inversely proportional to the diameter of B? Why?

17. Suppose that all the rest of the quantities in equation (12) remain the same, but that we double the diameter of B, what would happen to the R.P.M. of D?

18. Suppose that all the rest of the quantities in equation (12) remain the same, but that we triple the diameter of C, what would happen to the R.P.M. of D?

Gears

When one gear runs or is run by another gear they are said to *mesh*. In order for gears to mesh the teeth

on both gears must be of the same size regardless of the diameters of the gears. There are *driver* gears and *driven* gears. If one gear of a pair is a driver gear, then the gear with which it meshes must be a driven gear.

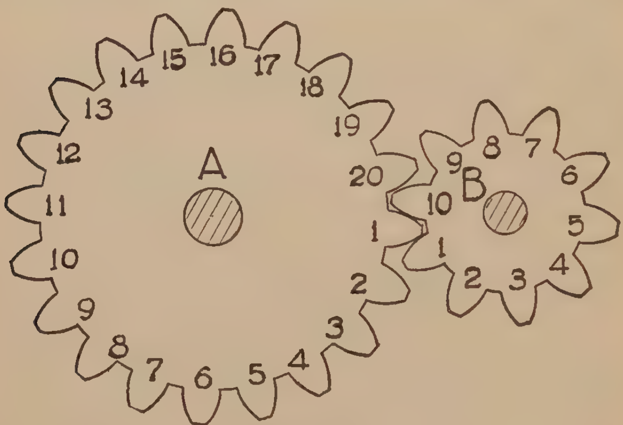


Figure 3

Consider the meshed gears of figure 3 and answer the following questions:

19. If B revolves in one direction, in what direction does A revolve?

20. When B has made one complete revolution, what tooth of A will tooth 10 of B be pushing?

21. When B has made two revolutions, how many revolutions has A made?

22. Considering B the driver, is the number of teeth in A directly or inversely proportional to the R.P.M. of A?

23. Prove that the following proportion is true:

$$\frac{\text{number of teeth in } A}{\text{number of teeth in } B} = \frac{\text{R.P.M. of } B}{\text{R.P.M. of } A}.$$

Instead of writing out the words "number of teeth in A," we shall understand that the letter A stands for the number of teeth in A. Hence:

$$(13)\quad \frac{A}{B}=\frac{\text{R.P.M. of } B}{\text{R.P.M. of } A}.$$

24. If A has 56 teeth and makes 39 R.P.M., how many R.P.M. does B make if it has 21 teeth?

25. If A has 48 teeth and makes 25 R.P M., how many teeth must B have to make at least 28 R.P.M.?

Gear Trains

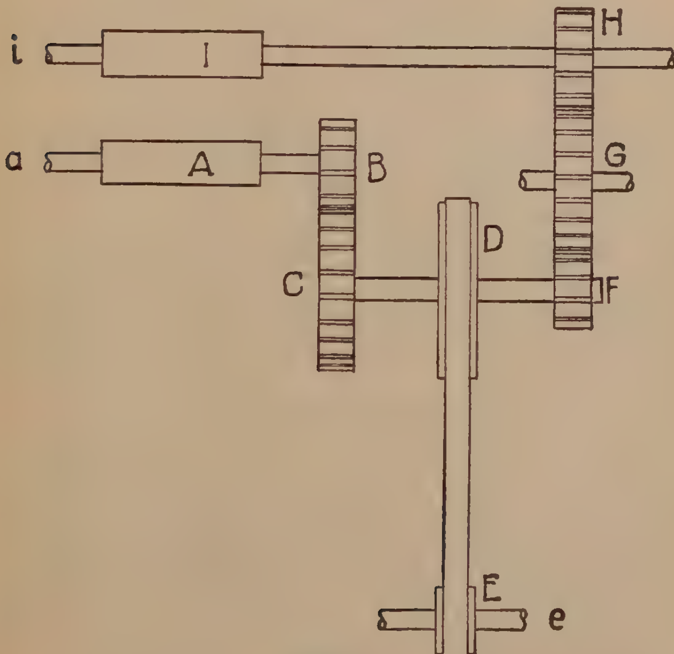


Figure 4

Consider figure 4. Suppose for the present that the power to this train of gears is supplied by the shaft a

to which the roll A and gear B are fastened. Gears C and F are fastened to the same shaft. Gear H and roll I are fastened to the shaft i. G is called an *intermediate* gear because it is intermediate between two other gears.

From equation (13) we know that:

$$(14)\ \frac{\text{R.P.M. of } B}{\text{R.P.M. of } C} = \frac{C}{B}; \quad (15)\ \frac{\text{R.P.M. of } F}{\text{R.P.M. of } G} = \frac{G}{F};$$

$$(16)\ \frac{\text{R.P.M. of } G}{\text{R.P.M. of } H} = \frac{H}{G}.$$

Multiplying the left sides of these equations together and the right sides together, we have:

$$(17)\ \frac{\text{R.P.M. of } B \times \text{R.P.M. of } F \times \text{R.P.M. of } G}{\text{R.P.M. of } C \times \text{R.P.M. of } G \times \text{R.P.M. of } H} = \frac{C \times G \times H}{B \times F \times G}.$$

But we know that because A and B, C and F, and H and I are on the same shafts, R.P.M. of A = R.P.M. of B, R.P.M. of C = R.P.M. of F, and R.P.M. of H = R.P.M. of I. Therefore, we can rewrite equation (17) as follows:

$$(18)\ \frac{\text{R.P.M. of } A \times \text{R.P.M. of } C \times \text{R.P.M. of } G}{\text{R.P.M. of } C \times \text{R.P.M. of } G \times \text{R.P.M. of } I} = \frac{C \times G \times H}{B \times F \times G}.$$

But we notice that R.P.M. of C and R.P.M. of G occur in both numerator and denominator of the left side and G occurs in both numerator and denominator of the right side. Canceling these we obtain:

$$(19)\ \frac{\text{R.P.M. of } A}{\text{R.P.M. of } I} = \frac{C \times H}{B \times F}.$$

26. By studying equation (19), supply the missing words (either *driver* or *driven*, whichever is correct) in the following statement: The R.P.M. of the first ...... shaft is to the R.P.M. of the last ...... shaft as the product of the teeth of the ...... gears is to the product of the teeth of the ...... gears.

27. By studying equations (15), (16), (17) and (18), tell why G does not appear in equation (19).

28. What effect does an intermediate gear have on the speed of the gears that come after it in a train of gears?

From equation (7) we learned that $\text{R.P.M.} = \frac{\text{surface speed}}{3.1416 \times \text{diameter}}$. Substituting this in equation (19) we obtain:

$$\frac{\frac{\text{S.S. of } A}{3.1416 \times \text{dia. of } A}}{\frac{\text{S.S. of } I}{3.1416 \times \text{dia. of } I}} = \frac{C \times H}{B \times F}.$$ Simplifying the left side we obtain:

$$\frac{\text{S.S. of } A \times 3.1416 \times \text{dia. of } I}{\text{S.S. of } I \times 3.1416 \times \text{dia. of } A} = \frac{C \times H}{B \times F}.$$ By multiplying both sides by $\frac{\text{dia. of } A}{\text{dia. of } I}$ and then canceling we obtain:

$$(20) \quad \frac{\text{S.S. of } A}{\text{S.S. of } I} = \frac{C \times H \times \text{dia. of } A}{B \times F \times \text{dia. of } I}.$$

29. By studying equation (20) supply the missing words (either *driver* or *driven*, whichever is correct) in the following statement: The surface speed of the ......roll is to the surface speed of the ...... roll as the product of the diameter of the ...... roll and the teeth of the ...... gears is to the product of the diameter of the ...... roll and the teeth of the ...... gears.

Change Gears. *F* is fastened to the shaft with a nut so that it can be changed. *F* is, therefore, a *change gear*.

30. Work out a formula for *F*.

Using the formula for F *from the preceding problem and using the following conditions: diameter of* A *is* 2″; *diameter of* I 2″; B 30 *teeth;* C 90 *teeth;* H 40 *teeth; solve the following problems:*

31. What must be the number of teeth in *F* to make the surface speed of *A* 5 times as great as the surface speed of *I*?

32. What must be the number of teeth in F to make the surface speed of A at least 7 times as great as the surface speed of I?

Thus far we have considered a *to be the driver shaft, now let us consider* i *to be the driver shaft.*

33. By studying figure 4, answer the following question: When i is the driver shaft, will the ratio of the S.S. of A to the S.S. of I be any different from what it is when a is the driver shaft, provided all the gears remain the same? Why?

34. In finding the ratio of the speeds of the first and last of a train, does it make any difference which we consider a driver and which we consider a driven?

As a matter of fact the shaft e *is the driver shaft of the train of pulleys and gears in figure* 4.

35. Will the fact that the power is supplied by shaft e make any difference in the ratio of the S.S. of A to the S.S. of I? Why?

Now let us see what is the relation of the speed of E to the speed of H. We know from equation (3) that:

$$(21)\quad \frac{\text{R.P.M. of } E}{\text{R.P.M. of } D} = \frac{\text{dia. of } D}{\text{dia. of } E}.$$

Now multiplying the left sides of equations (15), (16) and (21) together and the right sides we have:

$$(22)\quad \frac{\text{R.P.M. of } E \times \text{R.P.M. of } F \times \text{R.P.M. of } G}{\text{R.P.M. of } D \times \text{R.P.M. of } G \times \text{R.P.M. of } H} = \frac{\text{dia. of } D \times G \times H}{\text{dia. of } E \times F \times G}.$$

We know that R.P.M. of D = R.P.M. of F.

Hence, from the left side of (22) we can cancel R.P.M. of D, R.P.M. of F and R.P.M. of G, and from the right side we can cancel G. We, therefore, obtain:

$$(23)\quad \frac{\text{R.P.M. of } E}{\text{R.P.M. of } H} = \frac{\text{dia. of } D \times H}{\text{dia. of } E \times F}.$$

36. By studying equation (23) and figure 4, supply the missing words (*driver* or *driven*, whichever is correct)

in the following statement: In any train of pulleys and gears the ratio of the R.P.M. of the first ...... to the last ...... equals the product of the diameters of the ...... pulleys and the teeth of the ...... gears divided by the product of the diameters of the ...... pulleys and the teeth of the ...... gears.

37. Granting that shaft *e* supplies the power to the train in figure 4, will the speed of shaft *e* have any effect upon the ratio of the surface speed of *A* to the surface speed of *I*? Why?

38. If *e* is the driver shaft, out of the following list, by studying figure 4, pick out those quantities that are directly proportional to the surface speed of *I* and those that are inversely proportional to the surface speed of *I*, and state why:

(*a*) dia. of *E*. (*c*) *F*. (*e*) *H*.
(*b*) dia. of *D*. (*d*) *G*. (*f*) dia. of *I*.
(*g*) R.P.M. of *E*.

39. Now without reference to any other equation and merely on the basis of your reasoning in the preceding problem, and granting that you know the R.P.M. of *E*, write out a formula for the surface speed of *I*.

40. In the same manner write out a formula for the surface speed of *A*.

41. If diameter of *E* is 5″, diameter of *D* 20″, *C* has 90 teeth, *B* 30 teeth, the diameter of *A* is 2″ and the R.P.M. of *E* is 100, what is the surface speed of *A*?

Belts; Length of Belts

When it is not convenient or possible to pass a tape line around two pulleys to be connected by a belt the length of belt must be calculated. It is very expensive to cut belting by guesswork.

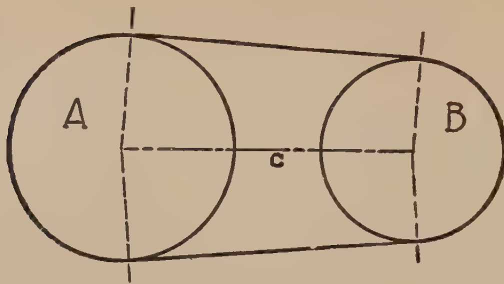


Figure 5

Consider figure 5, which represents two pulleys of about the same size connected by a belt. By looking up and down the dotted lines we see that the two straight portions of the belt are about the same length as the distance, c, between the centers of the pulleys.

42. Prove that in the case of two pulleys of about the same size:

$$\text{length of belt} = \frac{3.1416 \times \text{dia. of } A}{2} + \frac{3.1416 \times \text{dia. of } B}{2} + 2 \times c.$$

(24) **length of belt** $= 1.5708 \times (\text{dia. of } A + \text{dia. of } B) + 2 \times c.$

43. What length of belt is needed to connect two pulleys each 30″ in diameter, the distance from center to center being 10′?

44. What length of belt is needed to connect two pulleys, one 21″ in diameter and the other 29″, the distance between centers being 8′?

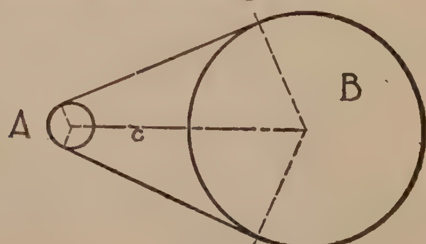


Figure 6

45. From figure 6, show why formula 24 does not apply to cases in which the diameter of one pulley is considerably smaller than the other.

Effective Diameter of Pulleys.

46. (*a*) If you examine a thick belt running on small pulleys you will see that the side of the belt in contact with the pulley is wrinkled, and the outside of the belt is stretched. Why is this?

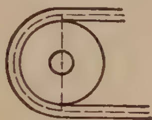


Figure 7

(*b*) By studying the preceding question and figure 7, tell why the real diameter or *effective diameter* of a pulley is the diameter of the pulley plus the thickness of the belt.

47. A 2″ pulley making 200 R.P.M. is running a $1\frac{1}{2}''$ pulley. The pulleys are connected with a belt $\frac{1}{4}''$ thick.

(*a*) What is the R.P.M. of the $1\frac{1}{2}''$ pulley taking into consideration the thickness of the belt?

(*b*) What is the R.P.M. of the $1\frac{1}{2}''$ pulley not taking into consideration the thickness of the belt?

48. A 40″ pulley making 200 R.P.M. is running a 30″ pulley. The pulleys are connected with a belt $\frac{1}{4}''$ thick.

(*a*) What is the R.P.M. of the 30″ pulley taking into consideration the thickness of the belt?

(*b*) What is the R.P.M. of the 30″ pulley not taking into consideration the thickness of the belt?

49. Comparing the results of the two preceding problems, tell why it is more important to consider the

thickness of the belt in the case of small pulleys than in the case of large pulleys.

Crossed Belts

A formula which gives the approximate length of crossed belts is as follows: Letting A and B stand for the two pulleys and c the distance between centers:

$$(25)\quad \text{length of belt} = 2 \times \sqrt{c^2 + \frac{(\text{dia.}\,A + \text{dia.}\,B)^2}{4}} + 1.5708 \times (\text{dia.}\,A + \text{dia.}\,B).$$

EXAMPLE: *What must be the length of a crossed belt to connect two pulleys* 12 *ft. apart, one* 2 *ft. and the other* 3 *ft. in diameter?*

Using formula (25):

$$\text{length} = 2 \times \sqrt{144 + \frac{(2+3)^2}{4}} + 1.5708 \times (2+3) = 2 \times \sqrt{144 + \tfrac{25}{4}} + 1.5708 \times 5 = 2 \times \sqrt{150.25} + 7.854 = 2 \times 12.25 + 7.854 = 24.50 + 7.854 = 32.354.$$

Answer: 32 ft. $4\frac{1}{4}$ in.

50. What must be the length of a crossed belt to connect two pulleys, eight feet apart, the diameter of one pulley being $2\frac{1}{2}$ ft. and the diameter of the other $3\frac{1}{2}$ ft.?

Levers

Levers occur in every cotton mill machine. There are three classes of levers: *first class, second class and third class,* as shown in figures 8, 9 and 10 respectively.

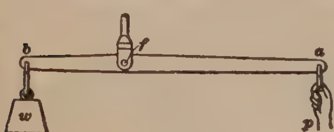


Figure 8
FIRST-CLASS LEVER

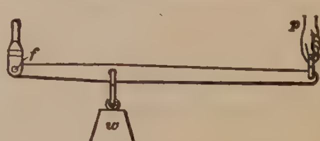


Figure 9
SECOND-CLASS LEVER

The point at which the lever is pivoted, *f*, is called the fulcrum. The lever is acted on by two *forces*, one being the weight *w*, which is called the *resistance;* and the other the hand, *p*, which is called the *power*. This distance from *f* to *b* is called the *resistance arm*, or the *weight arm*, and the distance from *f* to *a* is called the *power arm.*

When the hand, or power, moves the lever, the distance through which the power moves is called the *power distance;* the distance through which the weight moves is called the *weight distance.*

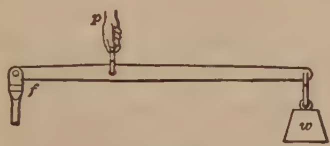


Figure 10
THIRD-CLASS LEVER

It was discovered long ago, as you can discover by trying it, that regardless of the class of lever, two proportions always exist between (*a*) the lengths of the arms and the forces and (*b*) the lengths of the arms and the distances as follows:

$$(26)\quad \frac{\text{weight arm}}{\text{power arm}} = \frac{\text{power}}{\text{weight}}, \text{ and}$$

$$(27)\quad \frac{\text{weight arm}}{\text{power arm}} = \frac{\text{weight distance}}{\text{power distance}}.$$

EXAMPLE: *If the weight in figure 2 is 50 lbs., the weight arm is 10″ and the power arm is 30″, how much of a force must the hand exert to balance the weight?*

Using equation (26):

$$\frac{10}{30} = \frac{p}{50}. \quad \therefore\ p = \frac{10 \times 50}{30} = 16\tfrac{2}{3}.$$

That is, the hand must pull up with a force equal to pulling up $16\frac{2}{3}$ lbs. in order to balance a force of 50 lbs.

EXAMPLE: *If the weight arm in figure 3 is 30″ and the power arm is 20″, how far downward shall the hand move to allow the weight to move downward 1″?*

Using equation (27) and letting pd stand for power distance:
$\frac{30}{20} = \frac{1}{pd}$. $\therefore pd = \frac{20 \times 1}{30} = \frac{2}{3}$. $\therefore$ the hand must move $\frac{2}{3}$″.

51. Fill in the correct words:

(*a*) The arms are ...... proportional to the forces.

(*b*) The distances are ...... proportional to the arms.

52. From equations (26) and (27) prove that:

$$(28)\quad \frac{\text{power}}{\text{weight}} = \frac{\text{weight distance}}{\text{power distance}}.$$

53. If in figure 1 the hand exerts a pull of 100 lbs. and moves 1″, the power arm is 100″ and the weight arm is 1″: (*a*) how much of a force is exerted at point b; and (*b*) how far does point *b* move?

54. On a certain spinning frame the distance on the roll weight lever from the point where the weight is hung to the bend where the stirrup is attached is 4″, from the stirrup to the lever screw (the fulcrum) is 1″, making the effective length of the lever 5″. If the weight is $3\frac{1}{2}$ lbs., with how much force or pressure are the three top rolls bearing on the bottom rolls?

55. On the frame in the preceding problem, what weight would have to be used to obtain a pressure on the top rolls of 30 lbs.?

56. The press roll weight lever of a slasher is 6″ long from the point where the lever is pivoted on the slasher frame to the center of the bearing of the lever on the press roll. From the center of the bearing to the end of the lever is 24″, making the lever 30″ long. How

far from the press roll bearing must the 50-lb. weight be placed to give a pressure of 200 lbs. on the press roll bearing?

Gear Blanks

Pitch. The *pitch circle* is the circle that runs through the points of contact of the teeth of one gear with the teeth of another gear. The *circular pitch* of a gear is the number of teeth in the gear divided by the circumference of the pitch circle. In other words, the circular pitch is the distance from the center of one tooth to the center of the next tooth measured along the pitch circle. The *diametral pitch* of a gear is equal to the number of teeth in the gear divided by the diameter of the pitch circle. Gears are measured either by their diametral or circular pitch. In order for gears to mesh they must have the same circular pitch, which means, of course, that they must have the same diametral pitch. *Pitch* means diametral pitch unless otherwise stated. Gear blanks before being cut are measured by the outside diameters of the blanks. The following formula will be found useful in picking out gear blanks.

$$\text{(29) dia. (in inches) of gear blank} = \frac{\text{number of teeth} + 2}{\text{diametral pitch}}.$$

Example: *We wish to have made a gear with* 34 *teeth. The gear with which it must mesh has* 60 *teeth and is* 5 *inches in diameter measured from the point of contact of one tooth to the point of contact of the tooth on the opposite side. What must be the size of the gear blank?*

$$\text{Diametral pitch} = \tfrac{60}{5} = 12.$$

$$\text{Diameter of gear blank} = \frac{34 + 2}{12} = 3.$$

Answer: 3 inches.

57. It is desired to cut a 6-pitch gear containing 22 teeth. What must be the diameter of the blank in inches?

58. A 10-pitch gear is to be cut containing 36 teeth. Find the diameter of the blank required.

59. What will be the required diameter of a blank for a 15-pitch gear containing 178 teeth?

60. What must be the diameter of the blank for a 9-pitch tape selvage drive gear to contain 98 teeth?

PART TWO

CHAPTER I

ROVING AND SINGLE YARN CALCULATIONS

The number or size of yarn is called the *counts* of the yarn. The number or size of roving is called the *hank roving* of the roving. The counts of yarn or the hank roving of roving means the number of hanks (840 yards) of that size required to weigh one pound. 5s means that the counts of the yarn is 5. 5 HR means that the hank roving of the roving is 5. The use of the term *counts* originated from *counting* the hanks required to make a pound. The term *hank roving* (short for "hanks of roving") originated from the hanks of roving required to make a pound.

EXAMPLE: *What is the counts of a yarn if* 1 *hank of the yarn weighs a pound?*

The counts = the number of hanks required to weigh a pound = 1. Therefore the counts of the yarn is 1. It is 1s yarn.

EXAMPLE: *What is the counts of a yarn if* 10 *hanks weigh* 1 *lb.?*

The counts of the yarn is 10. It is 10s yarn.

EXAMPLE: *What is the hank roving of a roving if* 1 *hank weighs* 2 *lbs.?*

The hank roving = the number of hanks required to weigh a pound = $\frac{1}{2}$. Therefore the hank roving is $\frac{1}{2}$ or .5. It is .5 HR.

EXAMPLE: *What is the hank roving if* 2560 *yds. weigh* 2 *lbs.?*

$\frac{2560 \text{ yds.}}{840 \text{ yds.}} = 3.$ 3 hanks weigh 2 lbs. $1\frac{1}{2}$ hanks weigh 1 lb., and therefore the hank roving is $1\frac{1}{2}$ or 1.5. It is 1.5 HR.

PROBLEMS. *If possible do these problems mentally. See how fast you can think out the correct answers. Find the counts if:*

1. 840 yards weigh $\frac{1}{4}$ lb.

2. 840 yards weigh $\frac{1}{10}$ lb.

3. 840 yards weigh $\frac{1}{100}$ lb.

4. 1680 yards weigh 1 lb.

5. 1680 yards weigh 2 lbs.

6. 1680 yards weigh $\frac{1}{2}$ lb.

7. 10 hanks weigh 10 lbs.

8. 10 hanks weigh 1 lb.

9. 1 hank weighs $\frac{1}{50}$ lb.

10. There are 20 hanks to a pound.

11. There are 100 hanks to a pound.

12. There is 1 hank to a pound.

The only essential difference between yarn and roving is the number of twists per inch. Roving is usually, though by no means always, coarser than yarn. Number 12 roving is common in fine goods mills and number 1 yarn is common in certain heavy goods mills.

PROBLEMS. *If possible do these problems mentally. Find the HR* (*short for "hank roving"*) *of the following roving if:*

13. 840 yards weigh $\frac{1}{12}$ lb.

14. 840 yards weigh $\frac{1}{10}$ lb.

15. 840 yards weigh $\frac{1}{8}$ lb.

16. 840 yards weigh $\frac{1}{2}$ lb.

17. 840 yards weigh 1 lb.

18. 840 yards weigh 2 lbs.

19. 840 yards weigh 4 lbs.

20. 840 yards weigh 5 lbs.

21. 10 hanks weigh 1 lb.

22. 5 hanks weigh 1 lb.

23. There are 4 hanks to 1 lb.

24. 1 hank weighs 5 lbs.

25. 2 hanks weigh 8 lbs.

26. $\frac{1}{7}$ of a hank weighs $\frac{1}{7}$ of a pound.

27. $\frac{1}{7}$ of a hank weighs $\frac{1}{14}$ of a pound.

28. $\frac{1}{7}$ of a hank weighs $\frac{2}{7}$ of a pound.

29. How many hanks to a pound of 30s?

30. How many hanks to a pound of 9s?

31. How many hanks to a pound of 5 HR?

32. How many hanks to a pound of .5 HR?

33. How many pounds to a hank of .5 HR?

34. How many pounds to a hank of .2 HR?

35. How many pounds in 1680 yds. of 2 HR?

36. How many pounds in 2520 yds. of 5 HR?

37. How many pounds in 3360 yds. of .5 HR?

38. How many pounds in 2520 yds. of 50s?

39. How many pounds in 8400 yds. of 10s?

40. How many pounds in 84,000 yds. of 100s?

41. How many pounds in 30,240 inches of 1 HR?

42. How many pounds in 90,720 inches of 30s?

43. How many pounds in 3,024,000 inches of 100s?

44. How many yards in a pound of 10s?

45. How many yards in $1\frac{1}{2}$ pounds of 40s?

46. How many yards in 10 pounds of 50s?

47. How many miles in a pound of 50s?

48. From the preceding problems work out the following formulas:

(1) $\text{counts (or hank roving)} = \dfrac{1}{\text{weight (in lbs.) of 1 hank}}$.

(2) $\text{hanks in 1 lb.} = \text{counts (or hank roving)}$.

(3) $\text{pounds in 1 hank} = \dfrac{1}{\text{counts (or hank roving)}}$.

(4) $\text{counts of any quantity of yarn (or hank roving of any quantity of roving)} = \dfrac{\text{number of hanks in the quantity}}{\text{weight (in lbs.) of the quantity}}$.

(5) $\text{hanks in any quantity of yarn (or roving)} = \text{wt. (in lbs.) of quantity} \times \text{counts (or hank roving)}$.

(6) $\text{pounds in any quantity of yarn (or roving)} = \dfrac{\text{number of hanks in the quantity}}{\text{counts (or hank roving)}}$.

Finding the Counts and Hank Roving at the Reel and Balance

From formula (1) we have:

$$\text{counts (or HR)} = \frac{1}{\text{wt. (in lbs.) of 1 hank}} = \frac{7000}{\text{wt. (in grs.) of 840 yds.}}$$

$$= \frac{1000}{\text{wt. (in grs.) of 120 yds.}} = \frac{100}{\text{wt. (in grs.) of 12 yds.}}. \text{ Hence:}$$

$$(7) \quad \text{counts (or HR)} = \frac{1000}{\text{wt. (in grs.) of 120 yds.}} = \frac{100}{\text{wt. (in grs.) of 12 yds.}}.$$

In finding the counts of yarn we reel off 120 yds. on the yarn reel, find its weight in grains on the yarn balance and divide this weight into 1000. To find the hank roving of roving we reel off 12 yds. on the roving reel and find its weight in grains and divide this weight into 100. With roving from the speeders and jack frames it is common to divide the weight of 24 yards into 200.

EXAMPLE: 120 *yds. of yarn weigh* 30.5 *grs., what is the counts?*

$$\text{Counts} = \frac{1000}{30.5} = 32.72.$$

PROBLEMS. *If possible do these problems mentally. Find the counts (or hank roving) if:*

49. 12 yds. weigh 500 grs.

50. 12 yds. weigh 400 grs.

51. 12 yds. weigh 200 grs.

52. 12 yds. weigh 100 grs.

53. 12 yds. weigh 50 grs.

54. 24 yds. weigh 50 grs.

55. 24 yds. weigh 25 grs.

56. 120 yds. weigh 100 grs.

57. 120 yds. weigh 50 grs.

58. 120 yds. weigh 40 grs.

59. 120 yds. weigh 25 grs.

60. 120 yds. weigh 20 grs.

61. 120 yds. weigh 10 grs.

62. 120 yds. weigh 5 grs.

The yarn reel has 4 spindles so that 120 yds. may be unwound from each of four bobbins and weighed at the same time, thereby finding the average counts of 4 bobbins.

63. 120 yds. from each of four bobbins weigh 208 grs. What is the counts?

64. 120 yds. from each of four bobbins weigh 62.5 grs. What is the counts?

65. Find the hank roving if 12 yds. from four bobbins of the same fly frame weigh 247.5, 249, 251 and 252.5 grs. respectively.

66. Find the hank roving if 24 yds. from each of four bobbins of the same frame weigh 117.5, 117.3, 117.5 and 117.7 grs. respectively.

67. Find the hank roving if 24 yds. weigh 51.3 grs.

68. What should be the weight of 120 yards of 36s?

69. What should be the weight of 120 yards of 42.5s?

Finding the Counts, Weight and Length of Small Quantities

From formula (4) we see that:

$$\text{counts (or HR) of any piece} = \frac{\text{number of hanks in piece}}{\text{wt. (in lbs.) of piece}} = \frac{\dfrac{\text{number of yds.}}{840}}{\dfrac{\text{wt. (in grs.)}}{7000}}$$

$$= \frac{8\frac{1}{3} \times \text{number of yds.}}{\text{wt. (in grs.)}}. \quad \text{Hence:}$$

$$(8) \quad \text{counts (or HR) of any piece} = \frac{8\frac{1}{3} \times \text{number of yds.}}{\text{wt. (in grs.)}}. \quad \text{Hence:}$$

$$(9) \quad \text{wt. (in grs.) of any piece} = \frac{8\frac{1}{3} \times \text{number of yds.}}{\text{counts (or HR)}}. \quad \text{Hence:}$$

$$(10) \quad \text{number of yds. in any piece} = \frac{3 \times \text{wt. (in grs.)} \times \text{counts (or HR)}}{25}.$$

70. If 15 yds. of yarn weigh $2\frac{1}{2}$ grains, what is the number of the yarn?

71. If 12 yds. of filling weigh 4 grs., what is the number of the filling?

72. 8 yards of warp weigh 3.28 grs., what is the number of the warp?

73. 3 yards of warp weigh 1.75 grs., what is the counts?

74. What will be the weight of 10 yds. of 20s?

75. What will 3 yds. of 36s weigh?

76. What is the weight of 36 yds. of .75 HR?

77. What is the length of 300 grs. of .25 HR?

Finding the Counts, Weight and Length of Large Quantities

78. It is evident that if a beam contains one counts of yarn only, the number of hanks on the beam equals the number of ends on the beam multiplied by the hanks in each end. Hence, from formula (4) prove:

$$\text{(11)}\quad \begin{array}{l}\text{counts of yarn}\\ \text{(or HR) on}\\ \text{beam, spool}\\ \text{or bobbin}\end{array} = \frac{\text{number of ends} \times \text{yds. in each end}}{840 \times \text{wt. (in lbs.) of yarn (or roving)}}.$$

79. If the warp on a beam contains 348 ends, is $27{,}314\frac{1}{2}$ yards long and weighs 492 pounds, what is the number of the yarn?

80. Find the counts of the warp on a beam of 330 ends, the length of which is 13,750 yards and the weight 415 pounds.

81. A warp on a warper beam contains 376 ends, is 26,554 yards long and weighs 566 pounds. What is the number of the warp?

82. If a spool holds 21,840 yards of yarn and weighs 2 pounds, what is the number of the yarn?

83. The warp on a beam contains 327 ends, is 27,500 yards in length, weighs $509\frac{1}{2}$ pounds. Find the number of the yarn.

84. From formula (11) prove the following formula:

$$\text{(12)}\quad \begin{array}{l}\text{yds. in}\\ \text{each end}\end{array} = \frac{840 \times \text{wt. (in lbs.)} \times \text{counts (or HR)}}{\text{number of ends}}.$$

85. Find the length of number 13 warp on a beam, which weighs 610 lbs. and contains 330 ends.

86. What is the length of 348 ends of number 23 warp on a beam the weight of which is 492 pounds?

87. Find the length of 376 ends of number 21 yarn on a beam the weight of which is 566 pounds.

88. A beam of number $11\frac{1}{2}$ warp, 370 ends, weighs 468 pounds. What is the length of the warp?

89. How many yards of 21s yarn on a spool, if the yarn weighs $1\frac{9}{10}$ lbs.?

90. A spool full of number 23 yarn weighs $1\frac{1}{4}$ pounds. Find the number of yards.

91. Find the number of yards of number 14 warp on a spool the weight of which is 2 pounds.

92. A full warp bobbin of 20s has a total weight of 960 grains. The empty bobbin weighs 440 grains. How many hanks and yards on the full bobbin?

93. A full $11 \times 5\frac{1}{2}$ slubber bobbin weighs 38 ounces. If the empty bobbin weighs 6 ounces, how many yards are there on the bobbin when full of: (*a*) .20-hank roving? (*b*) .50-hank roving?

94. A full $9 \times 4\frac{1}{2}$ slubber bobbin contains 20 ounces of roving. How many yards does it contain if full of 1.6-hank roving? How many hanks?

95. From formula (11) prove the following formula:

$$\text{(13)}\quad \begin{array}{l}\text{wt. of yarn (or}\\ \text{roving) on}\\ \text{beam, spool}\\ \text{or bobbin}\end{array} = \frac{\text{number of ends} \times \text{yds. in each end}}{840 \times \text{counts of yarn (or HR)}}.$$

96. What is the weight of number 20s warp on a warper beam that contains 380 ends, the length of each 24,750 yards.

97. Find the weight of number $11\frac{1}{2}$ warp on a beam containing $5\frac{1}{2}$ warps, 2750 yards to the warp, and 355 ends.

98. How much will the yarn on a beam weigh if it contains 10 warps (2750 yards each) of number 24s and 360 ends?

99. What will be the weight of the yarn on a spool that contains 23,520 yards of number 14 yarn?

100. What will be the weight of the yarn on a spool that contains 27,500 yds., of number 20 yarn?

101. From formula (11) prove that:

$$(14)\quad \text{number of ends on beam} = \frac{840 \times \text{wt. (in lbs.) of yarn on beam} \times \text{counts}}{\text{yds. in each end}}.$$

102. How many ends of number 24 warp yarn on a beam the length of which is 27,500 yards if its weight is 491 pounds?

103. Find the number of ends of number 13 yarn on a beam the weight of which is 582 pounds if its length is 19,258 yards.

104. Find the number of ends of number $11\frac{1}{2}$ yarn on a beam the length of which is 12,880 yards if its weight is 480 pounds.

Breaking Strength of Warp Yarn

The yarn reel is $1\frac{1}{2}$ yards around; hence, a skein of yarn on the reel contains 80 strands of yarn. In testing the breaking strength of warp yarn the skein is taken off the reel and placed on the strength tester. The pounds pressure required to break the 80 strands is the *breaking strength* of the yarn. There are many different standards of breaking strength for warp yarn. Standards vary from mill to mill. The new standard formulas are as follows:

(15) Breaking strength (in lbs.) of one skein of *carded* warp yarn must $= \frac{1800}{\text{counts}} + 3.$

(16) Breaking strength (in lbs.) of one skein of *combed* warp yarn must $= \frac{2500}{\text{counts}} - 4.$

EXAMPLE: *According to the new standard, what must be the breaking strength of 30s carded warp?*

$$\frac{1800}{30} + 3 = 63. \qquad \text{Answer: 63 lbs.}$$

105. What must be the breaking strength of 25s carded warp?

106. What must be the breaking strength of 25s combed warp?

107. Find out the standard used by your mill and then find the required strength of the warp yarn that your mill is running.

CHAPTER II

PLY YARN CALCULATIONS

Counts of Ply Yarns Composed of Yarns of the Same Counts

A ply yarn is always designated by the counts and the number of ends of the single yarn of which it is composed. Thus, when two ends of single 10s are twisted together the resulting yarn is called 2-ply 10s or 10s 2 ply. It may also be written 2/10s or 10s/2. However, in calculations ply yarn is treated in the same manner as single yarn.

Example: *Find the counts of* 2/40s.

Naturally a hank of ply yarn composed of two ends of 40s weighs 2 times as much as a hank of 40s single ply. Hence, the counts is half as much. Therefore, the counts of 2/40s = 20.

Problems. *Do these problems mentally if possible. Find the counts of:*

1. 2/10s.	**4.** 3/21s.	**7.** 4/60s.	**10.** 3/13s.
2. 2/20s.	**5.** 3/60s.	**8.** 5/70s.	**11.** 4/55s.
3. 2/35s.	**6.** 3/48s.	**9.** 6/60s.	**12.** 5/64s.

Counts of Ply Yarn Composed of Yarns of Different Counts

Example: *Suppose we wish to find the counts of the ply yarn resulting from twisting together* 1 *end of* 10s, 1 *end of* 20s *and* 1 *end of* 30s.

One hank of the ply yarn is made up of one hank of 10s, one hank of 20s and one hank of 30s. The hank of 10s weighs $\frac{1}{10}$ lb. The hank of 20s weighs $\frac{1}{20}$ lb. and the hank of 30s weighs $\frac{1}{30}$ lb. Hence, a hank of the ply yarn weighs $\frac{1}{10} + \frac{1}{20} + \frac{1}{30}$ of a lb. Therefore:

$$\text{counts of the ply yarn} = \frac{1}{\text{wt. (in lbs.) of 1 hank of ply yarn}} = \frac{1}{\frac{1}{10} + \frac{1}{20} + \frac{1}{30}}$$

$$= \frac{1}{\frac{20 \times 30}{10 \times 20 \times 30} + \frac{10 \times 30}{10 \times 20 \times 30} + \frac{10 \times 20}{10 \times 20 \times 30}}$$

$$= \frac{1}{\frac{20 \times 30 + 10 \times 30 + 10 \times 20}{10 \times 20 \times 30}}$$

$$= \frac{10 \times 20 \times 30}{20 \times 30 + 10 \times 30 + 10 \times 20} = \frac{6000}{1100} = 5.45. \quad \text{Hence:}$$

$$(1) \quad \text{counts of } 3/10\text{s } 20\text{s } 30\text{s} = \frac{10 \times 20 \times 30}{10 \times 20 + 10 \times 30 + 20 \times 30} = 5.45.$$

EXAMPLE: *Find the counts of 3/10s, 20s, 40s.*

$$\text{counts} = \frac{10 \times 20 \times 40}{10 \times 20 + 10 \times 40 + 20 \times 40} = 5.71.$$

PROBLEMS:

13. Find the counts of the ply yarn resulting from the twisting of 40s, 50s and 60s.

14. Find the counts of the ply yarn resulting from the twisting of one end each of 25s and 35s. Work out a method for doing this problem similar to equation (1).

15. If number 20 yarn and number 30 yarn are twisted together, what number of ply yarn will they make?

16. What number of ply yarn will be produced, if number 36 and number 40 yarn are doubled together?

17. What number of yarn will numbers 30, 50 and 60 twisted together make?

18. Find the number of ply yarn, that numbers 22, 28 and 44 will make if doubled together.

19. What number of ply yarn will numbers 60, 80 and 100 produce, if twisted together?

20. If a 3-ply yarn is made by twisting numbers 40, 60 and 80 together, find the number of the ply yarn.

21. What is the counts of a 4-ply yarn made up of 2 ends of 60s and 2 ends of 50s?

22. What is the counts of a 5-ply yarn made up of 2 ends of 32s and one end each of 40s, 50s and 60s?

Counts of Single Yarns Required to Make Ply Yarns

EXAMPLE: *What counts of yarn will double with 24s to make a 2-ply yarn equivalent to 14s?*

Let y stand for the yarn to be doubled with 24s. We know from formula (1) and the preceding problems that:

$$\frac{24 \times y}{24 + y} = 14. \quad \therefore 24 \times y = 14\ (24 + y).$$

$$\therefore 24 \times y = 14 \times 24 + 14 \times y.$$

Subtracting $14 \times y$ from each side:

$$24 \times y - 14 \times y = 14 \times 24.$$
$$\therefore (24 - 14) \times y = 14 \times 24.$$

Dividing each side by $(24 - 14)$:

$$y = \frac{14 \times 24}{24 - 14} = \frac{336}{10} = 33.6. \quad \text{Hence:}$$

$$(2)\quad \text{counts required to double with 24s to make 14s} = \frac{14 \times 24}{24 - 14} = 33.6.$$

EXAMPLE: *What counts of yarn is required to double with 60s to make a 2-ply yarn equivalent to 25s.*

$$\text{The counts of required yarn} = \frac{25 \times 60}{60 - 25} = 42.86.$$

PROBLEMS:

23. It is desired to make a 2-ply yarn equivalent to 12s using 1 end of 20s. What counts must be doubled with the 20s?

24. What counts of yarn must be doubled with 45s to make a ply yarn equivalent to 22s?

25. If number 36 yarn is to be used in making 16s ply yarn, what counts must be doubled with the 36s?

26. What yarn must be doubled with 50s to make 30s ply yarn?

Do the following problems mentally:

27. What counts must be doubled with 1 end of 50s to make 25s ply yarn?

28. What counts must be doubled with 1 end of 40s to make 20s ply yarn?

29. What counts must be doubled with 2 ends of 30s to make a 3-ply yarn equivalent to 10s?

30. What counts must be doubled with 4 ends of 100s to make a 5-ply yarn equivalent to 20s?

CHAPTER III

ACTUAL DRAFT CALCULATIONS

If four laps, each weighing 12 oz. for every yard of length, are being fed into the intermediate picker and only one lap, weighing 12 oz. for every yard, is being delivered by the breaker picker, the following facts are obvious:

(*a*) The *weight* per yard *fed* into the machine is *four* times the *weight* per yard *delivered.*

(*b*) The *length* per pound *delivered* is *four* times the *length* per pound *fed.*

(*c*) The *surface speed* of the *delivery roll* is *four* times the *surface speed* of the *feed roll.*

This *ratio* of weight fed to weight delivered, or length delivered to length fed, or surface speed of delivery roll to surface speed of feed roll, is called *draft.* Hence, we see that the draft in the preceding example is 4.

The draft based upon the ratio of weight fed to weight delivered, or length delivered to length fed, is called *actual draft.* The draft based upon the ratio of the surface speed of delivery roll to surface speed of feed roll is called *mechanical draft.* Hence:

$$(1)\quad \text{actual draft} = \frac{\text{wt. of 1 yd. fed}}{\text{wt. of 1 yd. delivered}} = \frac{\text{length of 1 lb. delivered}}{\text{length of 1 lb. fed}}.$$

$$(2)\quad \text{mechanical draft} = \frac{\text{surface speed of delivery roll}}{\text{surface speed of feed roll}}.$$

Actual draft always differs, at least slightly, from mechanical draft, as will be evident from the following example:

EXAMPLE: *The ratio of the surface speeds of the delivery rolls of an intermediate picker to that of the feed rolls is 4. 4 12-oz. laps are fed in and 1 lap is delivered. .3% of the weight of the laps fed into the machine consists of motes, fly and trash which are removed by the beating process of the machine. Find the actual draft and mechanical draft.*

$$\text{mechanical draft} = \frac{\text{surface speed of delivery roll}}{\text{surface speed of feed roll}} = 4.$$

If there were no loss due to the beating, each yard of cotton delivered would weigh 12 oz. But .3% of the weight of the cotton is lost. Hence, each yard delivered weighs 99.7% of 12 oz. = 11.964 oz. Hence, actual draft $= \dfrac{\text{weight of 1 yd. fed}}{\text{weight of 1 yd. delivered}}$

$$= \frac{4 \text{ (number of laps fed)} \times 12 \text{ oz. (wt. of each lap fed)}}{11.964 \text{ (weight of lap delivered)}} = \frac{4 \times 12}{11.964}$$

$= 4.01.$

The problems in this chapter deal with actual draft only. Mechanical draft is discussed in chapters VI and VII.

In the preceding example, 4 laps were fed into the intermediate picker. That is, the *doublings* is 4. Hence, the following basic formula for the actual draft of all machines:

$$(3)\quad \text{draft} = \frac{\text{doublings} \times \text{weight per yard fed}}{\text{weight per yard delivered}}.$$

FINDING THE DRAFT

PROBLEMS:

1. 4 15.85-oz. laps are fed into the **intermediate picker** and a 14.92-oz. lap is delivered. What is the draft?

2. 4 doublings of 15.02-oz. laps are fed and 15-oz. lap is delivered. What is the draft?

3. What is the draft if 13.26-oz. lap is delivered from 4 doublings of 13.5-oz. lap?

4. What is the draft if 12.75-oz. lap is delivered from 4 doublings of 14.98-oz. lap?

EXAMPLE: *A certain* **card** *receives* 14-*oz. lap and delivers* 61.25-*gr. sliver. What is the draft?*

$$\text{draft} = \frac{\text{doublings} \times \text{weight per yd. fed}}{\text{weight per yd. delivered}} = \frac{1 \times 14 \text{ oz.}}{61.25 \text{ gr.}}$$

$$= \frac{1 \times 14 \times 437.5 \text{ gr.}}{61.25 \text{ gr.}} = \frac{14 \times 437.5}{61.25} = 100.00.$$

5. A card receives 14.5-oz. lap and delivers 58.5-gr. sliver. Find the draft.

6. If a $12\frac{1}{2}$-oz. lap is run on a card and the sliver weighs 52 grs. per yard, what is the card draft?

7. If a card is running $10\frac{1}{4}$-oz. lap and it is desired to make 45-gr. sliver, what draft on card will be required?

8. Find the draft of a card making a 51-gr. sliver, if an $11\frac{3}{4}$-oz. lap is used.

EXAMPLE: *A* **drawing frame** *is producing* 60-*gr. sliver from* 6 62-*gr. slivers. Find the draft.*

$$\text{draft} = \frac{\text{doublings} \times \text{weight per yd. fed}}{\text{weight per yd. delivered}} = \frac{6 \times 62}{60} = 6.2.$$

9. If 6 ends of 56-gr. card sliver are run on a drawing frame, and the drawing frame sliver weighs 62 grs. per yd., what is the draft on the drawing frame?

10. Find the draft of a drawing frame running 6 ends of 43-gr. card sliver and making 48-gr. drawing frame sliver.

11. If 6 ends of 51-gr. card sliver are fed into a drawing frame and the drawing sliver weighs 58 grs. per yd., what is the draft of the drawing frame?

12. If the drawing frame sliver running on a slubber weighs 60 grs. per yd. and the slubber roving weighs 15 grs. per yd., what is the slubber draft?

13. If a slubber is making a roving of which 12 yds. weigh 168 grs., what is the draft, if the drawing sliver weighs 63 grs. per yd.?

The numbering system of cotton changes at the **slubber.** One end or doubling of gr. sliver is fed into the slubber and one end of roving delivered. From formula (9), chapter I, part II:

$$\text{weight (in grs.) of a piece of roving} = \frac{8\frac{1}{3} \times \text{yds. in piece}}{\text{hank roving}}.$$

$$\text{Hence, the weight (in grs.) of 1 yd. of roving} = \frac{8\frac{1}{3}}{\text{hank roving}}.$$

From formula (3) of this chapter:

$$\text{draft} = \frac{\text{doublings} \times \text{wt. per yd. fed}}{\text{wt. per yd. delivered}} = \frac{1 \times \text{gr. sliver}}{\dfrac{8\frac{1}{3}}{\text{hank roving}}}$$

$$= \frac{12 \times \text{gr. sliver} \times \text{hank roving}}{100}. \quad \text{Hence:}$$

$$\text{(4) slubber draft} = \frac{12 \times \text{gr. sliver} \times \text{hank roving}}{100}.$$

EXAMPLE: *What is the draft of a slubber receiving* 60-*gr. sliver and delivering* .60-*hank roving?*

$$\text{Using formula (4) draft} = \frac{12 \times 60 \times .60}{100} = 4.32.$$

14. If a drawing frame sliver whose weight is 62 grains per yd. is used to make number .64-hank roving, what draft will be required?

15. What draft is required to draft 58-gr. sliver into 60-hank roving?

16. What draft is required to make .32-hank roving from 78-gr. sliver?

At the intermediate, speeder and jack fly frames two ends of roving are drafted into one roving.

From equation (3):

$$\text{draft} = \frac{\text{doublings} \times \text{wt. per yd. fed}}{\text{wt. per yd. delivered}} = \frac{\text{doublings} \times \dfrac{8\frac{1}{3}}{\text{HR fed}}}{\dfrac{8\frac{1}{3}}{\text{HR delivered}}}$$

$$= \frac{\text{doublings} \times \text{hank roving delivered}}{\text{hank roving fed}}. \quad \text{Hence:}$$

$$(5)\quad \begin{array}{l}\text{intermediate}\\ \text{speeder and}\\ \text{jack draft}\end{array} = \frac{\text{doublings} \times \text{hank roving delivered}}{\text{hank roving fed}}.$$

17. What draft is required on an intermediate to draft 2 ends of .40-hank slubber roving into 1.20-hank roving?

18. If 2 ends of .66-hank (intermediate) roving are run together and drawn and twisted into one end on the front of the speeder making 1.98-hank speeder roving, what is the draft on the speeder?

19. If 2 ends of .64-hank roving are run together on the back of the speeder and the speeder roving is 1.94-hank roving, what is the draft on the speeder?

20. Find the draft on a speeder making 2.1-hank roving, if 2 ends of .68-hank roving are run together on the back.

Since the numbering of roving and yarn means exactly the same thing:

$$(6)\quad \text{spinning frame draft} = \frac{\text{doublings} \times \text{counts delivered}}{\text{hank roving fed}}.$$

21. If number $12\frac{1}{2}$ yarn is to be spun, using a single 1.78-hank roving, what will be the draft?

22. What will be the draft if number 24 yarn is spun, using double 3.6-hank roving?

23. Find the draft required to spin number 17.5 yarn, if a single 2.5-hank roving is used.

24. If a single 1.8-hank roving is spun into 12.6 yarn, what is the draft?

Finding the Weights Fed and Weights Delivered

By rearranging formulas (3), (4), (5) and 6 we can find either the weight fed or delivered when one weight and the draft are known.

Example: *If the draft of an intermediate picker is* 4.25, *what oz. lap of* 4 *doublings must be fed to produce* 14-*oz. lap?*

Rearranging formula (3) we have:

$$\text{weight per yard fed} = \frac{\text{draft} \times \text{weight per yd. delivered}}{\text{doublings}}$$

$$= \frac{4.25 \times 14 \text{ oz.}}{4} = 14.88 \text{ oz.}$$

25. If the draft on a card is 95, what grain sliver will be made if a 12-ounce lap is used?

26. What is the weight in grains of one yard of card sliver, if a $10\frac{3}{4}$-ounce lap is used, the card draft being 100?

27. What ounce lap will be required to make a 54-grain card sliver, if the draft of the card is 98?

28. If the draft is 100 on a card making 51-grain sliver, what ounce lap will be required?

29. Find the ounce lap that will make 45-grain card sliver, if the card draft is 99.65.

30. If the draft on a card is 99 and a 50-grain sliver is desired, what ounce lap will be required?

31. What ounce lap will be required to make a 45-grain sliver, if the card draft is 102?

32. A drawing frame is running 6 ends of 46-grain card sliver with a 5-draft. Find the grain drawing frame sliver being made.

33. What grain drawing frame sliver will 6 ends of 42-grain card sliver make, if the drawing frame draft is $4\frac{3}{4}$?

34. Find the grain sliver produced by running 6 ends of 52-grain card sliver drafted $4\frac{7}{8}$.

35. What grain card sliver, run 6 doubles, will be required to make 55.2-grain drawing frame sliver, if the draft is 5?

36. If the draft on a drawing frame is $5\frac{9}{10}$ and the weight of the drawing sliver 60 grains per yd., find the weight of the card sliver running 6 doubles.

37. What will be the number of slubber hank roving, if made with a 65-grain sliver drafted 5?

38. Find the number of hank roving made on a slubber whose draft is $4\frac{1}{2}$ if the drawing frame sliver weighs 60 grains per yd.

39. If a slubber has a draft of $4\frac{1}{2}$ and the roving numbers .644 hank, what is the weight in grains of one yard of the drawing frame sliver?

40. If the draft on a slubber is 4 and the hank roving numbers $.55\frac{5}{9}$ hank, find the weight of one yard of the drawing frame sliver.

41. What will be the number of the speeder roving, if 2 ends of .65 hank roving are run together on the back and the speeder draft is $5\frac{1}{2}$?

42. If 2 ends of .62-hank roving are run together on the back of a speeder with a $5\frac{7}{8}$ draft, what will be the number of the roving made?

43. Find the hank roving run 2 ends together that will produce a 1.79-hank roving on a speeder whose draft is $5\frac{1}{2}$.

44. What hank roving run 2 ends in creel, drafted $4\frac{1}{2}$, will be required to make 1.98-hank speeder roving?

45. Find the required hank roving run 2 ends in creel to produce 1.88-hank speeder roving, if the draft on the speeder is $4\frac{7}{8}$.

46. If the draft on the speeder is 4.8 and it is desired to make 1.92-hank roving, what number of roving, run 2 ends together in creel, will be required?

47. If the number of yarn is to be 24 and the desired draft of the spinning frame is $7\frac{1}{2}$, find the single hank roving required.

48. It is desired to make number 24 yarn, the draft is to be $7\frac{1}{2}$ and double roving is to be used. What hank roving will be required?

49. What single hank roving will be required to make number 13 yarn, the draft to be $6\frac{1}{2}$?

50. If the draft is $7\frac{1}{2}$ and the yarn being made is number 15, what single hank roving is being used?

51. What single hank roving will be required to make number $12\frac{1}{2}$ yarn if drafted 7?

CHAPTER IV

LAY AND TWIST CALCULATIONS OF YARN AND ROVING

Laps per Inch

In the "building" of bobbins of yarn and roving on the spinning and fly frames and in weaving it is sometimes necessary to know about how many strands of yarn or roving we can *lay* side by side in an inch. Hence, these are called *lay calculations*. The number of strands possible to lay side by side in an inch are referred to as *lays per inch* or *laps per inch*. In order to find the laps per inch it is evident we must first find the diameter of the yarn.

Let c stand for the counts of a certain size of yarn or roving.
Let d stand for the number of inches in the diameter of this yarn.
Let g stand for the number of lbs. in a cubic inch of this yarn.
Let us also confine our attention to 1 lb. only of this yarn.
$840 \times c$ = number of yds. in 1 lb. of this yarn.
$\therefore 36 \times 840 \times c$ = number of inches in 1 lb. of this yarn.
From our study of cubic measure we know that:

cubic inches in a cylinder = area (in sq. in.) of the base $\times$ number of inches in the length.

$\therefore \frac{d^2}{4} \times 3.1416 \times 36 \times 840 \times c$ = number of cubic inches in 1 lb. of this yarn.

We also know that the number of cubic inches in any object multiplied by the number of pounds in 1 cubic inch = the number of pounds in the object. In this case we are considering an object that weighs 1 pound. Hence:

$$\frac{d^2}{4} \times 3.1416 \times 36 \times 840 \times c \times g = 1.$$

$$\therefore d^2 = \frac{4}{3.1416 \times 36 \times 840 \times c \times g} = \frac{1}{23{,}750.496 \times c \times g}.$$

Then since the square roots of both sides of an equation are equal; and since the square root of a fraction equals the square root of the numerator divided by the square root of the denominator; and since the square root of a product equals the product of the square roots of the factors:

$$d = \frac{1}{\sqrt{23750.496} \times \sqrt{c} \times \sqrt{g}} = \frac{1}{154.06 \times \sqrt{g} \times \sqrt{c}}.$$

The number of strands that will occupy an inch is the number of times that the diameter will go into an inch.

$$\therefore \text{ laps per inch} = \frac{1}{\dfrac{1}{154.06 \times \sqrt{g} \times \sqrt{c}}} = 154.06 \times \sqrt{g} \times \sqrt{c}.$$

It has been found that a cubic inch of ordinary roving weighs on the average about .005 lb. and a cubic inch of hard spun warp yarn, being compressed by much twisting, weighs about .0541. $\therefore$ for roving $\sqrt{g} = \sqrt{.005} = .0707$ and for hard spun yarn $\sqrt{g} = \sqrt{.0541} = .2327$. Hence, laps per inch of roving $= 154.06 \times .0707 \times \sqrt{c} = 10.89 \times \sqrt{c}$, and of yarn $= 154.06 \times .2327 \times \sqrt{c} = 35.85 \times \sqrt{c}$. We must now consider the roughness of yarn and roving. Slubber roving having been drafted less than yarn is more uneven than yarn. And yarn, although the finest, is not perfectly even. Yarn in a tightly woven cloth is compressed by the weaving process. Hence, from the above equation, for laps per inch on the bobbin, where the yarn or roving must lie uncompressed, a deduction of about 15% on the average is necessary. For yarn in cloth the equation as it stands is about right. 85% of 10.89 = 9.3. 85% of 35.85 = 30. Hence, the following formulas represent average conditions.

(1) laps per inch of roving $= 9.3 \times \sqrt{\text{hank roving}}$.

(2) laps per inch of yarn $= 30 \times \sqrt{\text{counts}}$.

(3) laps per inch of yarn in cloth $= 36 \times \sqrt{\text{counts}}$.

(4) diameter of yarn in cloth $= \dfrac{1}{36 \times \sqrt{\text{counts}}}$.

EXAMPLE: *How many laps per inch of 25s yarn will lie side by side evenly on a bobbin?*

laps per inch of yarn on bobbin $= 30 \times \sqrt{\text{counts}} = 30 \times \sqrt{25}$
$= 30 \times 5 = 150$.

EXAMPLE: *About how many warp ends per inch will lie evenly in a plain two-harness weave composed of 36s warp and 36s filling?*

Diameter of warp in cloth $= \frac{1}{36 \times \sqrt{36}} = \frac{1}{216}$. Diameter of filling $= \frac{1}{216}$.

Combined diameter of one warp end interlaced with one filling pick $= \frac{1}{216} + \frac{1}{216} = \frac{2}{216} = \frac{1}{108}$. Laps per inch of warp and filling combined = 108. Answer: About 108.

PROBLEMS. *About how many laps per inch of the following will lie evenly on a bobbin:*

1. .64 HR? **3.** 1 HR? **5.** 4s? **7.** 25s? **9.** 65s?

2. .81 HR? **4.** 4 HR? **6.** 14s? **8.** 50s? **10.** 100s?

About what is the diameter of:

11. 1 HR? 25s on a bobbin? 25s in cloth?

12. 1s on a bobbin? 50s on a bobbin? 100s in cloth?

13. If a plain two-harness weave is composed of 25s warp and 36s filling, about how many warp ends per inch will lie evenly?

NOTE: All lay calculations are only approximate. This section on lay calculations is given to show also how the many necessary and practical yarn formulas are worked out.

TWISTS PER INCH

The preceding problems explain why all roving and yarn calculations that depend upon the diameter of the yarn or roving involve the square root of the counts. We know that cotton fibers must be twisted to keep them from slipping past each other. We also know that a thick object cannot be twisted as much as a thin object without being weakened or twisted in two.

Hence, the proper twists per inch to put into a yarn is inversely proportional to its diameter. And since, as we have just seen, the diameter is inversely proportional to the square root of the counts, the twists per inch must be directly proportional to the square root of the counts.

TWIST MULTIPLIERS AND TWISTS PER INCH OF SINGLE YARNS

There have been found by long experience and tests certain numbers, or *twist multipliers*, the products of which and the square roots of the counts (or hank roving) give the proper twists per inch to obtain the desired strength, hardness, softness or elasticity for the particular grade of cotton and counts being run.

(5) twists per inch = twist multiplier $\times \sqrt{\text{counts (or hank roving)}}$.

Depending upon these variable factors mills use yarn twist multipliers varying from 2.25 for fine soft hosiery yarns to 5.00 for hard spun warp yarns. Twist multipliers for roving vary from .70 to .150. Unless otherwise stated in this book, we will use the following multipliers which are in general use for ordinary cotton in mills making medium grades of cloth.

Ordinary spinning frame warp yarn twist multiplier = 4.75
Ordinary spinning frame filling yarn twist multiplier = 3.25
Roving twist multiplier = 1.20

EXAMPLE: *Find the twists per inch of 36s warp.*

twists per inch = $4.75 \times \sqrt{36} = 28.50$. Answer: 28.50 twists per inch.

PROBLEMS. *Find the proper twist for:*

14. .25 HR.

15. .50 HR.

16. 1 HR.

17. 4 HR.

18. 4s warp.

19. 20s filling.

20. 30s warp.

21. 40s filling.

22. Find the twists per inch of 30s soft hosiery yarn if the twist multiplier is 2.25.

23. Find the twists per inch of 32s ordinary hosiery yarn if the twist multiplier is 2.75.

24. Find the twists per inch of 100s warp if the twist multiplier is 4.25.

Twists per Inch and Twist Multipliers of Ply Yarns

The usual twist multipliers for regular ply yarns are as follows:

Ply yarn hard twist multiplier	= 6.00
Ply yarn medium twist multiplier	= 5.00
Ply yarn soft twist multiplier	= 4.00

Find the twists per inch of:

25. 2/18s soft.

26. 2/32s medium.

27. 3/48s hard.

28. 3/75s hard.

29. What twist multiplier has been used in twisting a 4-ply yarn if 120 yds. weigh 81.63 grains and the jaws of the twist counter make 168 turns in untwisting the plies of a 12-inch length?

Finding the Counts by Comparison of Diameters

Suppose the mill received an order to make cloth according to a small sample 3 inches square. The order does not state the counts of the yarn to be used. How can we determine the counts of the warp and filling without weighing the small bits of yarn in the sample?

We pick ten pieces of the unknown warp counts out of the sample and then take ten pieces of warp yarn the counts of which we know, and loop them together as shown at (*a*) in figure 1. Then we twist them together very tightly but without kinking as shown at (*b*). We see that the 10-ply yarn which we have made of known counts is slightly thicker than the 10-ply yarn which we have made of the unknown counts. We untwist, take out a single strand of the known counts, twist them again and compare. We keep taking out strands of the known counts until to the naked eye, or under the pick glass, the diameter of the known and unknown ply yarns appear to be equal. Now to find the counts of the unknown yarn:

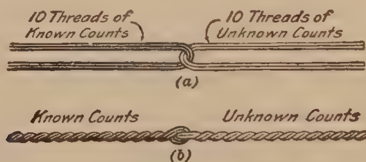


Figure 1

Suppose the known warp yarn is 30s. Let *cu* stand for the counts of the unknown warp yarn. And suppose that 8 twisted strands of the known counts appear to be equal in thickness to 10 strands of the unknown counts. Therefore:

Diameter of 8-ply 30s = diameter of 10-ply *cus*. But the counts of 8-ply 30s is equivalent to $\frac{30}{8}$, and the counts of 10-ply *cus* is equivalent to $\frac{cu}{10}$. Then from formula (4):

$$\frac{1}{36 \times \sqrt{\frac{30}{8}}} = \frac{1}{36 \times \sqrt{\frac{cu}{10}}}.$$

Multiplying both sides of this equation by 36 and then inverting and squaring both sides we have $\frac{30}{8} = \frac{cu}{10}$. Rearranging this equation we have $cu = \frac{10 \times 30}{8} = 37.5$. Hence, the counts of the unknown yarn is 37.5.

30. Work out the following formula from the preceding example:

$$(6)\quad \text{unknown counts} = \frac{\text{number of ends of unknown counts} \times \text{known counts}}{\text{number of ends of known counts}}.$$

31. 9 ends of 36s filling and 10 ends of unknown filling when looped and twisted are of equal diameters. What are the unknown counts?

32. 11 ends of 50s filling and 9 ends of unknown filling when looped and twisted are equal in diameter. Find the counts of the unknown filling.

33. 10 ends of 2-ply unknown warp counts and 7 ends of 2/30s warp looped and twisted are equal in diameter. What are the counts of the unknown warp?

34. Why not compare unknown warp with known filling or unknown filling with known warp?

CHAPTER V

CLOTH CALCULATIONS

The cloth calculations in this book do not deal with fancy cloth, that is, with cloth containing more than one kind of warp and more than one kind of filling in one piece of cloth. The calculations given in this chapter, however, are the basic calculations for all cloth, whether plain or fancy.

All cloth is made according to certain specifications called the *construction* of the cloth. Here is the complete construction of a certain kind of plain cloth:

40″ 2.90 48 × 48 15s warp 15.5s filling 48 selvage ends.

This construction means that the cloth is 40″ wide *between* the selvages; there are 2.90 yds. in a pound; there are 48 warp ends per inch in the body of the cloth; there are 48 picks of filling per inch; the warp yarn is 15s; the filling yarn is 15.5s, and that there are 48 selvage ends in both selvages—or 24 ends in each selvage. The warp ends per inch are always given immediately before the picks per inch. The warp ends per inch are often referred to as *ends per inch* or as the *sley*. Picks per inch are referred to as *picks*. The above construction would be read like this: "40–290–48 by 48 15s warp 15.5s filling." When the sley and the picks are the same the term *square* is used. Thus, the above cloth might be referred to as "48 square." The complete specifications are not always given in an order to the mill. Often a sample of the cloth is sent to the mill. Ducks and other heavy cloths are known by the ounces per yard instead of yards per pound.

Weight of Cloth

EXAMPLE: *What is the weight of* 1 *yard of* 36″ 4.50 48 × 52?

Weight of 4.5 yds. = 1 lb. Weight of 1 yd. $= \frac{1\ lb.}{4.5}$
$= .222$ lb. $= 3.55$ oz. $= 1555.4$ grs.

1. Find the weight in ounces of one yard of 31″ 3.00 44 × 40 sheeting.

2. What is the weight in pounds of 2 yards of 31″ 3.60 48 × 48 sheeting?

3. If $7\frac{1}{2}$ yards of a certain style cloth weigh one pound, how many grains are there in one yard?

4. Find the weight in grains of $\frac{1}{4}$ yard of 30″ 2.50 71 × 60 drills.

5. Find the weight in grains of $\frac{1}{8}$ yard of moleskin cloth if 1.65 yards weigh one pound.

6. Find the weight in ounces per yard of a bale of cloth which weighs 272 pounds and contains 12 pieces of 102 yards each.

7. If a $4\frac{1}{2}$-yard sheeting is baled 10 pieces to the bale, 110 yards to each piece, what will be the weight of 100 bales, allowing $\frac{5}{8}$ lb. per bale for burlap and ties?

Yards per Pound from Samples

Example: *A sample of cloth 3 inches square weighs 15 grains. Find the yards per pound if the cloth is to be made 30″ wide.*

The sample contains 3 in. × 3 in. = 9 square inches. 1 yd. of cloth would contain 30 in. × 36 in. = 30 × 36 square inches. But 9 sq. in. weighs 15 grs. 15 grs. $= \frac{15 \text{ lbs.}}{7000}$. ∴ by proportion:
$\frac{30 \times 36}{9} = \frac{\text{weight (in lbs.) of 1 yd.}}{\frac{15}{7000}}$. ∴ weight (in lbs.) of 1 yd.
$= \frac{15 \times 30 \times 36}{9 \times 7000}$. ∴ the yards in 1 lb. $= \frac{9 \times 7000}{15 \times 30 \times 36} = 2.92$.

8. From the preceding example work out the following formula:

$$(1)\ \text{yds. per lb.} = \frac{\text{square inches in sample} \times 7000}{\text{weight (in grs.) of sample} \times \text{width of cloth} \times 36}.$$

9. If a sample 4 inches square weighs 41 grains, find the number of yards 30 inches wide required to make one pound.

10. A sample of cloth 3 inches square weighs 15 grains. Find the number of yards per pound, if woven 28 inches wide.

11. A 4″ × 4″ sample weighs 20 grains. Find the number of yards to make a pound if the cloth is 36 inches wide.

12. The sample is ¼ of a yard square and weighs 84 grains. How many yards of this cloth will weigh one pound, if made 28 inches wide?

13. A sample of moleskin one inch square weighs 3.4 grains. It is desired to make the cloth 34½ inches wide. Find the number of yards per pound.

14. A sample is 2 × 2 inches and weighs 4 grains. What will be the yards per pound, if the cloth is 28 inches in width?

Number of Ends in Width of Cloth

Example: *How many warp ends in* 36″ 3.00 48 × 52 *if* 16 *extra ends are added for selvages?*

$48 \times 36 + 16 = 1744.$ Answer: total ends 1744.

15. How many warp ends will be required to make 40″ 2.75 44×40 sheeting with 20 ends for selvage?

16. If cloth is to be 31¼ inches wide, 72 warp ends per inch with no selvages, how many warp ends will be required?

17. Find the number of warp ends required to make 36″ 4.50 62 × 64 with 16 double ends in each selvage.

18. How many warp ends in 27″ 4.30 68 × 40, no selvage?

19. Find the number of ends required to make $39\frac{1}{2}''$ 48 × 44 sheeting, using 20 ends for selvage.

Ends per Dent and Total Dents Required

A dent is the opening between adjacent wires in the reed. Reeds are numbered according to the number of dents per inch or according to the total number of dents in a given length. Consider a reed containing 890 dents in a length of 40 inches. The number of this reed might be expressed in any one of the following ways:

(*a*) It is a 22.25-dent reed ($\frac{890}{40} = 22.25$); or a 22.25s reed; or the reed has 22.25 dents per inch; or the reed counts are 22.25s.

(*b*) It is an 890 – 40 reed; or 890 dents *are spread on* 40 inches.

A reed should always be the same length as the reed slot in the loom lay, regardless of the number of dents used or the width of the cloth woven.

EXAMPLE: *If there are* 1748 *ends in the warp including the selvages;* 16 *ends in the selvages; the selvages drawn* 4 *per dent, and the balance of the warp* 2 *per dent; what is the total number of dents required?*

$1748 - 16 = 1732$ ends in the body of the warp. $\frac{1732}{2} = 866$ dents in the body of the cloth. $\frac{16}{4} = 4$. $866 + 4 = 870$, the total dents required.

20. How many dents will be required to draw a 2142 end warp, with no selvages, 3 ends per dent?

21. Find the number of dents to weave a cloth containing 3648 ends including 28 selvage ends, all drawn 4 ends per dent.

22. How many dents are required to draw 36″ 3.25 44 × 48; warp drawn 2 ends per dent; selvages 32 ends drawn 4 ends per dent?

Percent of Contraction of Filling

The warp is spread out in the reed. After the filling interlaces with the warp, the warp ends are drawn together. The difference between the *width at reed* and the width of the finished cloth is the amount of *contraction of the filling.* The amount of contraction depends upon the manner in which the warp and filling interlace, the tension on the warp in the loom and the difference between the warp yarn counts and the filling yarn counts. The contraction in filling is often called *contraction in reed* or *shrinkage.*

Example: *What is the percent of contraction of filling if the width at reed is 25 inches and the width of cloth is* $23\frac{1}{2}''$?

$25-23.5=1.5.\ \frac{1.5}{25}=.06.$ Answer: contraction is 6%.

23. The width at reed is $31\frac{5}{8}''$ and the width of the cloth is 30″. What is the percent of contraction?

24. The finished cloth is 36″ wide and the width at reed is $37\frac{5}{8}''$. What is the percent of filling contraction?

25. The finished cloth is 60″ wide and the width at reed is $62\frac{3}{4}''$. Find the percent of contraction.

26. Find the width of the cloth, if the warp in reed is 33 inches and the contraction from warp in reed to cloth is 6%.

27. How many inches wide is the warp in the reed, if the contraction from warp in reed is 8%, and the cloth is 40 inches wide?

Dents per Inch Required and Total Dents in Reed

Example: *Find the dents per inch required in the reed to make sheeting with 48 ends per inch in the cloth if the ends are drawn 2 per dent and the contraction is $7\frac{1}{2}\%$.*

$\frac{48}{2} = 24$. $\therefore$ 48 ends occupy 24 dents. $100\% - 7\frac{1}{2}\% = 92.5\%$. $\therefore$ there are 92.5% of 24 dents in 1 inch. $.925 \times 24$ dents $= 22.2$ dents. Answer: 22.2 dents per inch required.

28. How many dents per inch will be required in a reed to make a sateen, containing 110 ends per inch in the cloth, reeded 5 ends per dent, if the contraction in width is 5%?

29. Find the number of dents in a reed $40\frac{1}{4}''$ long required to make $30''$ 88×56 twills, reeded 4 ends to the dent, the contraction in width being 5%.

30. Find the number of dents in a reed $40\frac{1}{4}''$ long required to make $34''$ 3.00 108×56 sateen, drawn 5 ends to the dent, allowing 5% for contraction.

31. Find the number of dents in a reed $44\frac{1}{4}''$ long required to make $38''$ 96×64 drills, reeded 3 ends per dent, if the contraction in width from warp in reed to cloth is $3\frac{1}{2}''$.

32. It is desired to make cloth $38\frac{1}{2}''$ 44×40, reeded one end to the dent. The contraction in width in reed is $8\frac{1}{2}\%$. Find the number of reed dents to be spread on $44\frac{1}{2}$ inches.

33. Find the number of reed dents to be spread on $40\frac{1}{4}$ inches, to make $30''$ 2.50 72×60, if the contraction in width at reed is $8\frac{7}{8}\%$.

Width of Warp at Reed

Example: *Find the total width at reed of 38″ 44 × 40 reeded two ends per dent with 24 selvage ends reeded four per dent if the contraction in width is 5%.*

Width (in inches) of body of cloth at reed $= \frac{38}{.95} = 40$. Dents per inch $= .95 \times 22 \doteq 20.9$. Dents occupied by selvages $= 12$. $\therefore$ width (in in.) of selvages at reed $= \frac{12}{20.9} = .57 = .6$. $\therefore$ total width at reed $= 40.6$ inches.

34. Find the width at reed of 30″ 88 × 56 with 16 extra selvage ends, all reeded 4 per dent, allowing 5% contraction.

35. Find the width at reed of 36″ 64 square reeded 2 per dent with 16 extra selvage ends reeded 4 per dent, allowing 6% contraction.

36. Find the width at reed of 34″ 108 × 56 with no selvages, allowing 5% contraction.

37. Find the width of warp at reed of 36″ 48 × 52 with no selvages, allowing 4% contraction.

Weight of Filling in Cloth

It is evident that each pick of filling in the cloth before contraction takes place is exactly the width at the reed of the cloth including the selvages. Hence, calculations to find the weight of filling in cloth must be based upon the total width at reed.

Example: *Find the weight of 20s filling in 1 yard of 38″ 44 × 40, reeded 2 ends per dent, with 24 selvage ends, reeded 4 per dent if the contraction in width is 5%.*

By calculations explained under "Width of Warp at Reed," we find the width of warp including selvages to be 40.6″.

40.6 = inches of filling in 1 pick. 40.6×40 = inches of filling in 1 inch of cloth. $40.6 \times 40 \times 36$ = inches of filling in 1 yard of cloth. 40.6×40 = yards of filling in 1 yard of cloth. $\frac{40.6 \times 40}{840}$ = hanks of filling in 1 yard of cloth. From formula (6), chapter I: pounds of filling in 1 yard of cloth $= \frac{\frac{40.6 \times 40}{840}}{20} = \frac{40.6 \times 40}{20 \times 840} =$ .0967. ∴ lbs. of filling in 1 yard of cloth = .0967. If the weight in grains were required, from the preceding work we see that: weight (in grs.) $= \frac{40.6 \times 40 \times 7000}{20 \times 840} = 676.66$. ∴ grains of filling in 1 yard of cloth = 676.66.

38. From the above example work out the following formulas for the weight of filling in any length of cloth:

$$\text{(2) lbs. of filling in cloth} = \frac{\text{yds. of cloth} \times \text{width (in in.) at reed} \times \text{picks per inch}}{840 \times \text{counts of filling}}.$$

$$\text{(3) grs. of filling in cloth} = \frac{25 \times \text{yds. of cloth} \times \text{width (in in.) at reed} \times \text{picks per inch}}{3 \times \text{counts of filling}}.$$

39. Find the weight in grs. of 24s filling in 1 yd. of 36″ 64 square reeded 2 per dent with 16 extra selvage ends reeded 4 per dent, allowing 6% contraction.

40. Find the weight in grs. of 30s filling in 1 yd. of 30″ 48 × 54 reeded 2 per dent with 24 extra ends in each selvage reeded 4 per dent, allowing 7% contraction.

41. Find the weight in grs. of 30s filling in 1 yard of 30″ 88 × 60 with 16 extra selvage ends all reeded 4 per dent, allowing 5% contraction.

42. What is the weight in lbs. of the filling in 60 yards of 34″ 3.00 110 × 56 sateen, no selvages, using number 23 filling, if the contraction of the filling is 6%?

43. What is the weight in lbs. of the filling in one pound of 36″ 4.50 48 × 52, no selvages, if number 22 filling is used and contraction is 4%?

44. Find the weight in lbs. of number 20 filling in 60 yards 30″ 5.00 48 × 48, no selvages, figuring the filling contraction 6%.

45. How many pounds of number 14 filling will be required to make 60 yards 34″ 1.65 64 × 112 moleskin, no selvages, allowing 4% for contraction?

Percent of Contraction of Warp

The length of the warp from the slasher is always greater than the length of the woven cloth. The amount of *contraction of the warp* is affected by the amount of interlacing, the diameter of the warp and the filling, and the tension of the warp on the loom. Therefore, the contraction is greater on some weaves than on others and no given percent of contraction will hold good on different weaves.

Example: *How many yards of warp yarn will be required to make one yard of cloth containing* 1744 *ends, if the contraction in length of warp is* 5%?

100% − 5% = 95%. 1744 × 1 yd. = 1744 yds. = yds. of contracted warp yarn in 1 yd. of cloth. $\therefore \frac{1744}{.95} = 1835.78$ = number of yards of warp yarn in 1 yd. of cloth.

46. A piece of warp yarn is picked out of a piece of cloth exactly 3″ long. The warp yarn after being smoothed out evenly measures $3\frac{1}{4}$ inches. What is the percent of contraction of warp?

47. Find the number of yards of warp in 3 yards of 36″ 3.00 44 × 40 sheeting, 16 extra ends for selvage, if the contraction in length is $4\frac{1}{4}$%.

48. How many yards of warp in one pound of 30″ 2.50 72 × 60, no selvage ends, allowing $4\frac{1}{2}$ percent for contraction?

49. Find the total number of yards of warp in one pound of 36″ 4.70 48 × 52 with 16 ends for selvage, allowing $5\frac{3}{4}\%$ for contraction in length.

50. How many yards of warp in one pound of 31″ 4.60 44 × 40 sheeting 16 extra ends for selvage, if the warp contraction is 5%?

51. If a cut measures $60\frac{1}{2}$ yards, what was the length of the warp at the slasher, if the contraction is $8\frac{1}{2}\%$ of the length in weaving?

52. How many yards of cloth can be woven from a warp whose length at the slasher is 66 yards, if the contraction in weaving amounts to $6\frac{1}{4}\%$?

Weight of Warp in Cloth

To find the total weight of warp in a given length of cloth, we must first find the weight of the length of warp which when contracted will make the given length of cloth. And then to the weight of this length of yarn we must add whatever weight of sizing compound has been added to the yarn.

EXAMPLE: *What is the weight of the warp in one yard of cloth* 40″ *wide with* 40 *ends of* 20s *warp per inch plus* 16 *extra ends for selvage, if the contraction of warp is* 6% *and* 8% *of sizing has been added to the warp?*

Number of yards of contracted warp in one yard of cloth = $40 \times 40 + 16 = 1616$. $100\% - 6\% = 94\% = .94$. Number of yards of uncontracted warp in 1 yd. of cloth $= \frac{1616}{.94}$. Hence:

hanks of warp in cloth $= \dfrac{\frac{1616}{.94}}{840} = \dfrac{1616}{.94 \times 840}$. From formula (6), chap. I:

$$\text{pounds of unsized warp} = \frac{\frac{1616}{.94 \times 840}}{20} = \frac{1616}{.94 \times 840 \times 20}.$$

$100\% + 8\% = 108\% = 1.08$. $\therefore$ pounds of warp with sizing in 1 yd. of cloth $= \dfrac{1616 \times 1.08}{.94 \times 840 \times 20} = .1105$. $\therefore$ grs. of warp with sizing in 1 yd. of cloth $= \dfrac{1616 \times 1.08 \times 7000}{.94 \times 840 \times 20} = 773.57$.

53. From the preceding example work out the following formula for the weight in lbs. of the sized warp in any length of cloth.

$$(4)\ \text{lbs. of sized warp in cloth} = \frac{\text{yds. of cloth} \times \text{number of ends} \times (100\% + \%\text{ of size})}{(100\% - \%\text{ of contraction}) \times 840 \times \text{counts}}.$$

54. Find the weight of the warp in 5 yards of 30″ 2.50 71 × 60 made with number $11\frac{1}{2}$ warp, no selvage, allowing $5\frac{1}{2}\%$ for contraction and $8\frac{1}{2}\%$ for size.

55. How many pounds of warp in 60 yards of cloth 34 inches wide, 64 ends of $11\frac{1}{2}$ warp per inch, allowing 6% for contraction and $8\frac{1}{4}\%$ for size, 16 extra ends for selvage?

56. What is the weight in pounds of the warp in one pound of 36″ 4.70 48 × 52 sheeting, number 20 warp, 16 extra ends for selvage, allowing 9% for size and 6% for contraction?

57. Find the weight in ounces of the warp in 60 yards of $38\frac{1}{2}$″ 2.85 96 × 64 jeans, no extra selvage ends, number 23 warp, allowing 4% for contraction and 6% for size.

Calculating the Desired Information from the Given Cloth Specifications

The specifications for cloth to be made by the mill often give only a minimum amount of information. Sometimes the only information is the width and a small sample of the cloth. From the specifications given, however, all the rest of the essential information must be found out. The problems in this chapter up to this point have covered the basic cloth calculations. With a command of these basic calculations you can solve any of the following problems. In some of the following problems you will have to reverse the calculations you have learned. For instance: some of the problems require you to find the counts of the warp instead of finding the weight of the warp having given the counts. A little thinking, however, will enable you to reason out the correct method.

Example. *The mill receives orders to make cloth of the following specifications. From these specifications all the necessary information must be found. The specifications are: "Width 40″ as per attached sample."*

The sample is about $3\frac{1}{2}''$ square and contains one selvage. By using the pick glass we find the following:

A. Sley, 48. *B*. Picks, 48. *C*. Ends in each selvage, 24. *D*. Body of warp drawn, 2 per dent. Selvages, 4 per dent. Selvages, same counts as body of warp.

We then trim off the selvage and trim the body of the cloth to exactly 3″ square and weigh it.

E. Weight of sample 3″ square, 15.0 grs.

The sample is then picked apart and the warp yarn and filling yarn weights found to be as follows:

F. Weight of filling, 7.26 grs. *G*. Weight of warp plus size, 7.74 grs. It is observed that these check exactly with the weight of the sample.

Next we straighten out one end of warp and one end of filling, and find:

H. Length of uncontracted warp, $3\frac{1}{4}''$. *I.* Length of uncontracted filling, $3\frac{3}{8}''$.

With the preceding information we make the following calculations:

(*a*) Using formula (1):

$$\text{yards of cloth per lb.} = \frac{9 \times 7000}{15 \times 40 \times 36} = 2.92.$$

(*b*) Contraction in filling:

$3\frac{3}{8}'' - 3'' = \frac{3}{8}''$. Percent of contraction $= \dfrac{\frac{3}{8} \times 100}{3\frac{3}{8}} = 11.11\%$ or 11.1%.

(*c*) Contraction in warp:

$3\frac{1}{4}'' - 3'' = \frac{1}{4}''$. Percent of contraction $= \dfrac{\frac{1}{4} \times 100}{3\frac{1}{4}} = 7.69$ or 7.7%.

(*d*) Number of ends in body of cloth $48 \times 40 = 1920$.

(*e*) Number of ends in selvages $24 \times 2 = 48$.

(*f*) Total number of ends $1920 + 48 = 1968$.

(*g*) Dents per inch: $\frac{48}{2} = 24$. $100\% - 11.1\% = 88.9\%$. Dents per inch $= .889 \times 24 = 21.34$.

(*h*) Width of cloth in reed: Dents in selvages $= \frac{48}{4} = 12$. Width in inches of selvages in reed $= \dfrac{12}{21.34} = .5623$. Width in inches of body of warp in reed $= \dfrac{40}{.889} = 44.994$. Total width in inches of warp at reed $= 44.994 + .562 = 45.556$ or 45.6.

(*i*) Counts of filling yarn: total length in yds. of filling yarn $= \dfrac{3\frac{3}{8} \times 48 \times 3}{36} = \dfrac{27}{2}$. From formula (9), chapter I:

$$\text{counts} = \frac{8\frac{1}{3} \times \frac{27}{2}}{7.26} = 15.49 \text{ or } 15.5\text{s}.$$

(*j*) Counts of warp yarn: total length in yds. of warp yarn $= \dfrac{3\frac{1}{4} \times 48 \times 3}{36} = 13$. The weight of the warp yarn in sample plus

the size = 7.74 grs. From experience it is judged that 7% is about the right allowance for size. Weight (in grains) of unsized warp yarn $= \frac{7.74}{1.07} = 7.23$. Counts $= \frac{8\frac{1}{3} \times 13}{7.23} = 14.97$ or 15s.

(*k*) Yards per pound from weight of filling and warp: In (*a*) we found the yds. per lb. to be 2.92. To check the accuracy of the preceding calculations, let us now compare this calculation for yds. per lb. with the yds. per lb. calculated from the filling and warp counts. Using formulas (2) and (4): lbs. of filling in 1 yd. of cloth $= \frac{1 \times 45.6 \times 48}{840 \times 15.5} = .168$. Lbs. of warp in 1 yd. of cloth $= \frac{1 \times 1968 \times 1.07}{.923 \times 840 \times 15} = .181$.

Weight in lbs. of 1 yd. of cloth = .168 + .181 = .349. Yds. in 1 lb. $= \frac{1}{.349} = 2.87$.

Comparing the yds. per lb. calculated both ways we see that our calculations check to within .05 of a yard per lb. This difference is caused by the calculation of the yds. per lb. direct from the sample in (*a*) taking no account of the weight of the selvages. It is also practically impossible to cut and weigh such a small sample correctly to an exact degree. This sample is, therefore, from a cloth of these specifications:

40″ 2.90 48 × 48 15s warp 15.5s filling 48 selvage ends.

58. Find the yards per pound of 36″ 64 × 64 20s warp 24s filling, drawn 2 per dent with 16 extra selvage ends drawn 4 per dent, allowing 5% contraction of warp, 6% contraction of filling and 5% size.

59. Find the yards per pound of 30″ 88 × 60 30s warp 30s filling with 16 extra selvage ends all reeded 4 per dent, the selvage ends made of 2/30s, allowing 5% contraction of filling, 8% size and 4% contraction of warp.

60. Find the warp counts necessary to make 30″ 7.00 48 × 54 30s filling, body of cloth reeded 2 per dent with 24 extra ends in each selvage reeded 4 per dent, if the contraction in filling is 7%; contraction in warp 5% and 8% size has been added to the warp.

61. Find the counts of filling necessary to make 30″ 2.50 71×60 11.5s warp, no selvages, allowing $5\frac{1}{2}$% for contraction of warp, $8\frac{1}{2}$% for size and 10% for contraction of filling.

62. Find the counts of filling necessary to make 36″ 4.70 48×52 sheetings 20s warp drawn 2 per dent with 16 extra ends for selvage drawn 4 per dent, allowing 9% for size, 6% for contraction of warp and 8% for contraction of filling.

63. Find the picks per inch of 25s filling necessary to make cloth 38.5″ wide with no selvages, 96 sley, 23s warp, allowing 6% for size, 4% for contraction of warp and 5% for filling contraction.

64. In problem 63 find the following: (*a*) the percent of filling in the cloth; (*b*) the percent of warp plus size in the cloth.

65. If you have access to a pick glass and scales, analyze samples of cloth from your mill. Calculate all the necessary information for the weaving of the cloth. Find out, from someone who knows, whether or not your figures are correct. Check your reed calculations with the reed and cloth on the loom. Also, check your calculations for counts by use of formula (6), chapter IV.

CHAPTER VI

PICKER CALCULATIONS

Draft of Breaker Pickers

Figure 1 represents a breaker picker. From our study of draft we know that:

draft $= \frac{\text{surface speed of delivery roll}}{\text{surface speed of feed roll}}$. In this case the feed roll is J, the roll that feeds the beater. The delivery **roll is** P, the front calender roll that delivers the breaker lap. Hence, letting S.S. stand for surface speed in inches per minute, we have:

(1) draft $= \frac{\text{S.S. of } P}{\text{S.S. of } J}$. From what we have learned of surface speed and R.P.M. we know that:

$$(2)\quad \frac{\text{R.P.M. of } P}{\text{R.P.M. of } J} = \frac{\text{S.S. of } P \times \text{dia. of } J}{\text{S.S. of } J \times \text{dia. of } P}.$$

From our study of gear trains we know that:

$\frac{\text{R.P.M. of } P}{\text{R.P.M. of } J} = \frac{E^1 \times G \times H \times I \times J^1}{P^1 \times E^2 \times G^1 \times H^1 \times I^1}$. Substituting from (2) we have:

$$\frac{\text{S.S. of } P \times \text{dia. of } J}{\text{S.S. of } J \times \text{dia. of } P} = \frac{E^1 \times G \times H \times I \times J^1}{P^1 \times E^2 \times G^1 \times H^1 \times I^1}.$$

Dividing each side by dia. of J and dia. of P:

$\frac{\text{S.S. of } P}{\text{S.S. of } J} = \frac{E^1 \times G \times H \times I \times J^1 \times \text{dia. of } P}{P^1 \times E^2 \times G^1 \times H^1 \times I^1 \times \text{dia. of } J}$. Substituting from (1):

$$(3)\quad \text{draft} = \frac{E^1 \times G \times H \times I \times J^1 \times \text{dia. of } P}{P^1 \times E^2 \times G^1 \times H^1 \times I^1 \times \text{dia. of } J}.$$

This breaker picker is built for one draft only. There are no change gears for changing the draft.

Hereafter in many of our equations we shall omit the word "of." Thus, R.P.M. of P may appear as R.P.M. P; S.S. of P as S.S. P; dia. of P as dia. P; cir. of P as cir. P, and so on.

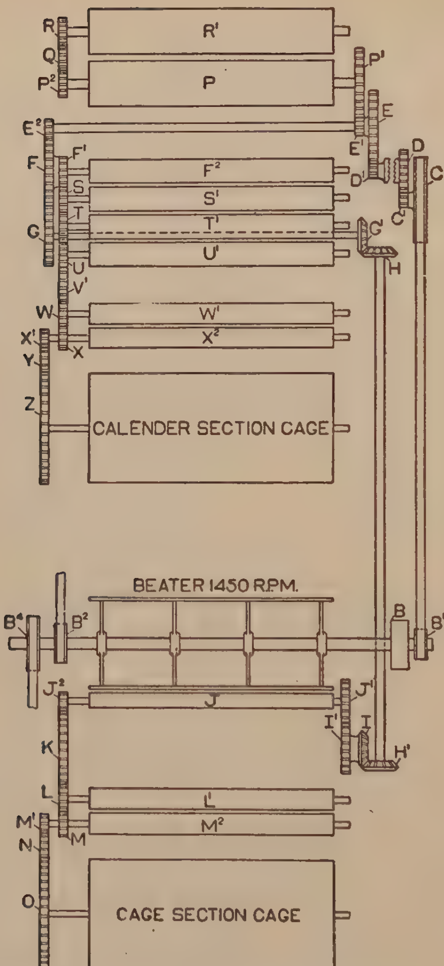


Figure 1. GEARING DIAGRAM OF BREAKER PICKER

Combination Number	Diameter of				Teeth in Gear													
	B^1	C	J	P	C^1	D	D^1	E	E^1	E^2	G	G^1	H	H^1	I	I^1	J^1	P^1
1	3″ to 13″ (Note)	18″	2″	9″	15	35	17	96	12	14	30	24	24	28	28	37	33	53
2		18″	2″	9″	18	42	16	90	14	21	40	28	28	24	24	40	36	56
3		18″	2″	9″	12	28	18	102	10	14	30	28	28	24	24	40	36	44
4		18″	2″	9″	12	28	18	96	12	21	42	24	24	28	28	32	30	54

NOTE: B^1 furnished in full-inch and half-inch diameters.

In the table are shown some of the combinations with which breaker pickers are built. The feed pulley B^1 which drives the entire picker with the exception of the beater and fans can be changed.

EXAMPLE: *Find the draft of the breaker picker in figure* 1 *if the gears and rolls are as shown in combination* 1 *of the table.*

Using formula (3) we have:

$$\text{draft} = \frac{E^1 \times G \times H \times I \times J^1 \times \text{dia. } P}{P^1 \times E^2 \times G^1 \times H^1 \times I^1 \times \text{dia. } J}$$

$$= \frac{12 \times 30 \times 24 \times 28 \times 33 \times 9}{53 \times 14 \times 24 \times 28 \times 37 \times 2} = 1.95.$$

PROBLEMS:

1. Find the draft of the breaker picker in figure 1 with gears and rolls as shown in combination 2 of the table.

2. Find the draft of the breaker picker in figure 1 with gears and rolls as shown in combination 3 of the table.

3. Find the draft of the breaker picker in figure 1 with gears and rolls as shown in combination 4 of the table.

Production, Production Constants and Feed Pulleys of Breaker Pickers

Between gears D and D^1 is the clutch which is shown open. Consider it closed in the following computations.

It is evident from figure 1 that the R.P.M. of B^1 = R.P.M. of the beater. From what we have learned of pulleys, belts and gears, we see that:

$$\frac{\text{R.P.M. } P}{\text{R.P.M. beater}} = \frac{\text{dia. } B^1 \times C^1 \times D^1 \times E^1}{\text{dia. } C \times D \times E \times P^1}. \quad \text{Hence:}$$

$$\text{R.P.M. } P = \frac{\text{dia. } B^1 \times C^1 \times D^1 \times E^1 \times \text{R.P.M. beater}}{\text{dia. } C \times D \times E \times P^1}$$

and hence:

$$\frac{\text{S.S. } P}{\text{cir. } P} = \frac{\text{dia. of } B^1 \times C^1 \times D^1 \times E^1 \times \text{R.P.M. beater}}{\text{dia. } C \times D \times E \times P^1}.$$

Therefore:

$$\text{S.S. } P = \frac{\text{dia. } B^1 \times C^1 \times D^1 \times E^1 \times \text{R.P.M. beater} \times \text{cir. } P}{\text{dia. } C \times D \times E \times P^1}.$$

But the surface speed of P is the same as the amount of lap passing over P. Hence, the above surface speed is the *inches* of lap produced by the picker in *one minute*. Hence, the production of *yards* of lap in *ten hours* would be expressed as follows:

production of yds. in 10 hrs. =

$$\frac{10 \times 60 \times \text{dia. } B^1 \times C^1 \times D^1 \times E^1 \times \text{R.P.M. beater} \times \text{cir. } P}{36 \times \text{dia. } C \times D \times E \times P^1}.$$

Now to find the production in *ounces* we must *multiply* the production in *yards* by the *ounces* in each yard of lap. And to find the production in *pounds* we must *divide* the production in *ounces* by 16. Hence, letting production mean 100% production of pounds in 10 hours we have:

production =

$$\frac{10 \times 60 \times \text{oz. lap} \times \text{dia. } B^1 \times C^1 \times D^1 \times E^1 \times \text{R.P.M. beater} \times \text{cir. } P}{16 \times 36 \times \text{dia. of } C \times D \times E \times P^1}.$$

Hence, dividing both sides of this equation by oz. lap, dia. B and R.P.M. beater and canceling the numbers on the right side and substituting the figures from combination 1 we have:

$$(4)\ \frac{\text{production}}{\text{oz. lap}\times\text{dia. }B^1\times\text{R.P.M. beater}}=\frac{25\times C^1\times D^1\times E^1\times\text{cir. }P}{24\times\text{dia. }C\times D\times E\times F^1}$$
$$=\frac{25\times15\times17\times12\times28.2744}{24\times18\times35\times96\times53}$$
$$=.0281.$$

Hence, we see that on any picker the ratio of the production to the product of the oz. lap, diameter of the feed pulley and the R.P.M. of the beater always equals a fixed number, or *constant*, regardless of the production, the oz. lap, the size of the pulley or the speed. This fixed number is called the *production constant*. Therefore, the production constant of the picker equipped with combination 1 is .0281. From equation (4) and letting *pc* stand for production constant we obtain these formulas:

(4*a*) production $= pc \times$ oz. lap $\times$ dia. feed pulley $\times$ R.P.M. beater.

Therefore:

$$(4b)\ \text{dia. feed pulley}=\frac{\text{production}}{pc\times\text{oz. lap}\times\text{R.P.M. beater}}.$$

EXAMPLE: *How many pounds of* 14-*oz. lap will be produced by the breaker picker in figure* 1 *equipped with combination* 1 *and an eight-inch feed pulley if the R.P.M. of the beater is as shown and allowing* 10% *for stoppage due to doffing, cleaning, etc.?*

Using formula (4*a*) and the production constant found in equation (4): production $= .0281 \times 14 \times 8 \times 1450 = 4563.4$. $.90 \times 4563.4$ lbs. $= 4107$ lbs.

Find the production per 10-*hour day of the picker in figure* 1 *equipped with combination* 1, *allowing* 10% *for stoppage if:*

4. The beater makes 1450 R.P.M., the feed pulley is 10 inches in dia., and 16-oz. lap is run.

5. The beater makes 1200 R.P.M., the feed pulley is 8 inches in dia., and 14-oz. lap is run.

6. A certain make of picker has a production constant of .0213. Find the production of 12-oz. lap for 10 hrs.

if the beater makes 1450 R.P.M. and the feed pulley is 6 inches in diameter, allowing 10% for stoppages.

EXAMPLE: *What must be the size of the feed pulley of the picker in figure* 1 *to produce* 4400 *lbs. of* 16-*oz. lap in* 10 *hrs. if the beater makes* 1450 *R.P.M. and* 10% *is allowed for stoppage?*

Using formula (4*b*): dia. of feed pulley $= \dfrac{4400}{.0281 \times 16 \times 1450}$ $= 6.74.$ $\dfrac{6.74}{.90} = 7.48.$ Answer: $7\frac{1}{2}$ inches in diameter.

7. What size pulley must be used to produce 4466 lbs. of 12-oz. lap if the beater speed is 1450 R.P.M. and the production constant is .0213?

8. A certain make of breaker picker has a production constant of .04 and a beater speed of 1000 R.P.M. What size feed pulley must be used to produce 4200 lbs. of 18-oz. lap in 10 hrs., allowing 10% stoppage?

DRAFT OF INTERMEDIATE OR FINISHER PICKERS

Breaker and intermediate or finisher pickers are very similar. Hence, any discussion of breaker pickers serves as an introduction to finisher pickers. Figure 2 shows the gearing of a finisher picker. Consider the cones, P^1 and Q, as two pulleys connected by a belt. When the thick place in the breaker picker lap goes over the feed roll T an automatic *evener motion* shifts the cone belt to the right, thereby slowing up the cone Q, and consequently the feed roll T slows up and feeds the thick spot into the beater at a slower speed. Similarly, a thin spot shifts the cone belt to the left. Consider the spiral gears, R and Q^1, as two bevel gears with an equal number of teeth. R^1 is a double worm. Hence, R^1 in one revolution takes up two teeth on the worm gear S. P and C^2 are change gears. Some pickers have only one change gear.

As will be seen from figure 2, shifting the cone belt changes the speed of the feed rolls which of course changes the draft. When slight draft changes are to be made the cone belt is moved by the hand wheel. Large changes are made by changing the change gears.

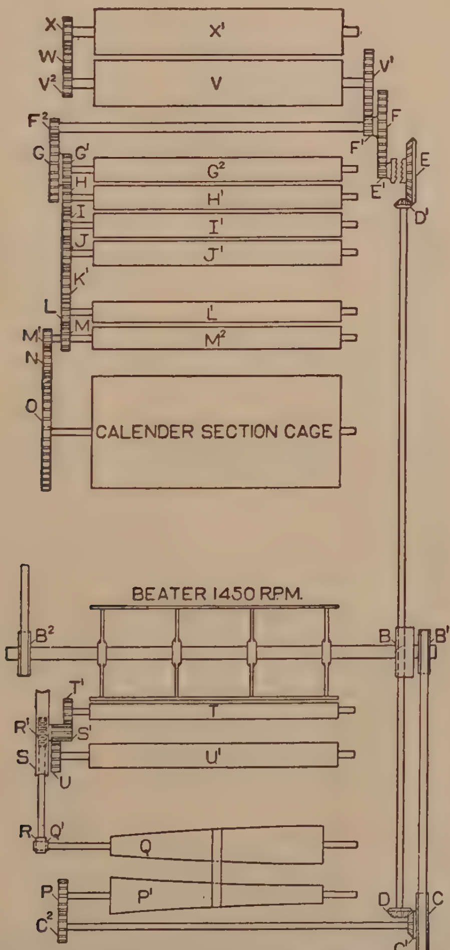


Figure 2. INTERMEDIATE OR FINISHER PICKER

Some of the gearing and pulley combinations of figure 2 are shown in the following table.

Combination Number	1	2	3	4
Blades in beater	2	2	3	3
Diameter of B^1	3″ to 13″ in half and full-inch sizes.			
" " C	12″	12″	12″	12″
" " P^1 (Note)	Tapers from 2 inches to 12 inches.			
" " Q (Note)	Tapers from 12 inches to 2 inches.			
" " T	3″	3″	3″	3″
" " V	9″	9″	9″	9″
Teeth in C^1	27	24	28	30
" " C^2 (Note)	55 to 35	55 to 35	55 to 35	55 to 35
" " D	27	24	28	30
" " D^1	18	21	24	24
" " E	60	70	80	80
" " E^1	17	20	20	20
" " F	96	114	114	114
" " F^1	12	12	14	13
" " F^2	14	21	14	21
" " G	50	75	50	75
" " G^1	27	28	30	30
" " M^1	23	24	25	25
" " O	181	130	132	184
" " P (Note)	35 to 55	35 to 55	35 to 55	35 to 55
" " Q^1	9	9	9	9
" " R	9	9	9	9
" " R^1	Double Worm	Double Worm	Double Worm	Double Worm
" " S	78	78	78	78
" " S^1	12	14	16	16
" " T^1	24	28	32	32
" " V^1	53	54	56	52

Note: Since in this picker the two change gears, C^2 and P, are on fixed shafts, the distance between their centers cannot be changed. Hence, the sum of their radiuses must remain the same; and consequently the sum of their teeth must remain the same. In this machine $C^2 + P$ must always $= 90$.

NOTE: Every manufacturer builds his pickers with a definite normal position of the belt on the cones. The normal position in this machine is where the diameter of Q is 6.4″ and P^1 is 4″. Draft is figured from the normal position.

PROBLEMS:

9. In the same manner that we worked out formula (3), work out the following formula:

$$(5)\quad \text{draft} = \frac{T^1 \times S \times R \times P \times C^1 \times D^1 \times E^1 \times F^1 \times \text{dia.}\,V \times \text{dia.}\,Q}{S^1 \times R^1 \times Q^1 \times C^2 \times D \times E \times F \times V^1 \times \text{dia.}\,T \times \text{dia.}\,P^1}.$$

EXAMPLE: *Find the draft of the intermediate picker in figure* 2 *with gearing shown in combination* 1 *of the preceding table, basing the draft on the normal position of the cone belt; and the change gears* C^2 *and* P *having* 45 *teeth each.*

Using formula (5):

$$\text{draft} = \frac{24 \times 78 \times 9 \times 45 \times 27 \times 18 \times 17 \times 12 \times 9 \times 6.4}{12 \times 2 \times 9 \times 45 \times 27 \times 60 \times 96 \times 53 \times 3 \times 4} = 4.504.$$

10. Find the draft of the intermediate picker in figure 2 with gearing shown in combination 1; normal position of cone belt; and C^2 and P having 40 and 50 teeth respectively.

11. Find the draft in figure 2; gearing as shown in combination 1; normal position of cone belt; and P and C^2 having 40 and 50 teeth respectively.

12. What would be the draft in problem 10 if the cone belt were shifted by a thin place in the lap to a position on the cones where the diameters of Q and P^1 are equal? *Hint:* Do this problem by proportion, using the answer of problem 10.

INTERMEDIATE OR FINISHER PICKER DRAFT GEARS

13. From formula (5) prove that:

$$(6)\quad \frac{C^2}{P} = \frac{T^1 \times S \times R \times C^1 \times D^1 \times E^1 \times F^1 \times \text{dia.}\,V \times \text{dia.}\,Q}{S^1 \times R^1 \times Q^1 \times D \times E \times F \times V^1 \times \text{draft} \times \text{dia.}\,T \times \text{dia.}\,P^1}.$$

EXAMPLE: *What must be the size of the draft change gears,* C^2 *and* P, *in order to insert a draft of* 4.25 *with combination* 1?

Using equation (6):

$$\frac{C^2}{P} = \frac{24 \times 78 \times 9 \times 27 \times 18 \times 17 \times 12 \times 9 \times 6.4}{12 \times 2 \times 9 \times 27 \times 60 \times 96 \times 53 \times 4.25 \times 3 \times 4} = 1.06.$$

Hence, $\frac{C^2}{P} = 1.06$. $\therefore C^2 = 1.06 \times P$. But $C^2 + P = 90$. Substituting $1.06 \times P$ for C^2: $1.06 \times P + P = 90$. $\therefore 2.06 \times P = 90$. $\therefore P = \frac{90}{2.06} = 43.7$.

Hence, P must have 43 teeth and therefore C must have $90 - 43$ teeth, or 47 teeth.

PROBLEMS AND QUESTIONS:

14. Answer the following questions by studying equation (6):

(*a*) Does increasing the number of teeth in the driver change gear, C^2, increase or decrease the draft? Why?

(*b*) Does increasing the number of teeth in the driven change gear, P, increase or decrease the draft? Why?

(*c*) Therefore is a driver change gear directly or inversely proportional to the draft; and is a driven change gear directly or inversely proportional to the draft?

(*d*) Does the beating out of trash and fiber by the beater tend to increase or decrease the draft as regards weight fed and weight delivered?

(*e*) Therefore why did we drop the decimal in finding the teeth in P in the above example?

(*f*) If the 43-tooth driven gear found in the above example gives us too heavy a weight of lap, must we shift the cone belt in figure 2 to the right or left?

15. What must be the sizes of the draft change gears

on the picker in figure 2 to insert a draft of 4.00 with combination 1 and the cone belt in normal position?

16. What must be the sizes of the draft change gears in problem 15, to obtain a draft of 4.50?

INTERMEDIATE OR FINISHER PICKER DRAFT CONSTANTS

The use of draft constants greatly shortens the labor of calculating draft and draft gears (short for "draft change gears"). From equation (6) and using the figures in combination 1 we have:

$$(7)\ \frac{C^2}{P}\times\text{draft}=\frac{T^1\times S\times R\times C^1\times D^1\times E^1\times F^1\times\text{dia. }V\times\text{dia. }Q}{S^1\times R^1\times Q^1\times D\times E\times F\times V^1\times\text{dia. }T\times\text{dia. }P^1}$$

$$=\frac{24\times 78\times 9\times 27\times 18\times 17\times 12\times 9\times 6.4}{12\times 2\times 9\times 27\times 60\times 96\times 53\times 3\times 4}$$

$$=4.503.$$

Hence, as long as the diameters of the rolls and cones, the normal position of the cone belt and the rest of the gears remain unchanged, the *product* of the ratio of the draft change gears and the draft always remains equal to a certain fixed number, or constant, regardless of the sizes of the change gears and the amount of draft. This fixed number is called the *draft constant*. Hence, the draft constant for the picker in figure 2 with combination 1 is 4.503. Letting *dc* stand for draft constant, *drg* stand for driver draft gear, and *dng* stand for driven draft gear, we have from equation (7) the following useful formulas:

$$(8)\ dc=\frac{drg}{dng}\times\text{draft.}\qquad(9)\ \frac{drg}{dng}=\frac{dc}{\text{draft}}.$$

$$\therefore\ (10)\ \text{draft}=dc\times\frac{dng}{drg}.$$

EXAMPLE: *If the picker in figure 2 is equipped as in equation* (7), *what draft gears will insert a draft of* 3.75?

Using formula (9): $\frac{drg}{dng}=\frac{4.503}{3.75}=1.2.\quad\therefore\ drg=1.2\times dng.$ But $drg+dng=90.\quad\therefore\ 1.2\times dng+dng=90.\quad\therefore\ 2.2\times dng=90.$ $\therefore\ dng=\frac{90}{2.2}=40.9.$ $\therefore$ driven change gear must have 40 teeth and the driver change gear must have 50 teeth.

Finding the Draft Change Gears

17. Find the draft gears required on the picker in figure 2 with combination 1 to insert a draft of 3.92.

18. What draft gears on the picker in figure 2 with combination 1 will insert a draft of 4.62?

19. Suppose the picker in figure 2 had a draft constant of 5.00, what draft gears would insert a draft of 4.00?

20. Suppose the picker in figure 2 had a draft constant of 5.25, what draft gears would insert a draft of 4.25?

21. Suppose the picker in figure 2 had a draft constant of 5.40, what draft gears would insert a draft of 3.60?

Finding the Draft

Example: *If the picker in figure 2 is equipped as in equation (7), what draft will a 54-tooth driver draft gear insert?*

Driven gear = 90 − 54 = 36. Using formula (10), draft = $4.503 \times \frac{36}{54} = 3.002$.

22. What draft will be inserted by a 35-tooth driven gear on the picker in figure 2 with combination 1?

23. What draft will be inserted by a 55-tooth driven gear on the picker in figure 2 with combination 1?

24. Suppose the picker in figure 2 had a draft constant of 5.00. What draft would a 48-tooth driven gear insert?

25. Suppose the picker in figure 2 had a draft constant of 5.25. What draft would a 45-tooth driver gear insert?

26. Suppose the picker in figure 2 had a draft constant of 4.45. What draft would a 52-tooth driver gear insert?

Finding the Approximate or Actual Draft Constant

Example: *By weighing the breaker lap and the intermediate lap we find that the picker has an actual draft of 4.46. The draft was inserted with a 42-tooth driven draft gear. What is the approximate or actual draft constant?*

Using formula (8), draft constant $= \frac{drg}{dng} \times \text{draft} = \frac{48}{42} \times 4.46 = 5.10.$

Note: The constant approximated in this manner will differ from the exact draft constant because of slippage of the cone belt, cone belt not at normal position, slight irregularities in the lap, removal of waste, etc.

27. If the draft of a picker is 4.1 and the driver draft gear is 46, what is the approximate draft constant?

28. If the draft of a picker is 3.78 and the driven draft gear is 48, what is the approximate draft constant?

29. A 55-tooth driver draft gear is inserting a draft of 3.50, what is the approximate draft constant?

Finding the Draft Constant

The only way in which the draft constant may be found *exactly* is by calculating from the gears, cones and rolls as we did in equation (7).

Find the draft constant of the picker in figure 2 if:

30. The picker is equipped as shown in combination 2.

31. The picker is equipped as shown in combination 3.

32. The picker is equipped as shown in combination 4.

Combinations of Picker Draft Formulas

Combination of *mechanical* draft formulas and *actual* draft formulas reduce the labor of calculating.

To find the required draft gears when the present draft gears, present draft and required draft are known:

Let "sub-one" ($_1$) after a word or letters mean "present"; and "sub-two" ($_2$) after a word or letters mean "required." From equation (8) we have:

$$dc = \frac{drg_2}{dng_2} \times \text{draft}_2. \quad dc = \frac{drg_1}{dng_1} \times \text{draft}_1.$$

The left sides of these two equations are equal. $\therefore$ the right sides are equal, and $\therefore \frac{drg_2}{dng_2} \times \text{draft}_2 = \frac{drg_1}{dng_1} \times \text{draft}_1$. Hence:

$$(11)\quad \frac{drg_2}{dng_2} = \frac{drg_1}{dng_1} \times \frac{\text{draft}_1}{\text{draft}_2}.$$

Example: *A* 40-*tooth driver gear is inserting a draft of* 4.70. *What gears will insert a draft of* 4.20?

Present driven gear = 90 − 40 = 50. Using formula (11) $\frac{drg_2}{dng_2} = \frac{40}{50} \times \frac{4.70}{4.20} = .895.$

$\therefore drg_2 = .895 \times dng_2$. $drg_2 + dng_2 = 90$. $\therefore .895 \times dng_2 + dng_2 = 90$. $\therefore 1.895 \times dng_2 = 90$. $\therefore dng_2 = \frac{90}{1.895} = 47.5$. $\therefore$ the required driven gear must have 47 teeth and the required driver gear must have 43 teeth.

To find the required draft gears when the present draft gears, present ounce lap delivered and required ounce lap delivered are known, the ounce lap fed remaining the same:

From formula (11) we have:

$$\frac{drg_2}{dng_2} = \frac{drg_1}{dng_1} \times \frac{\text{draft}_1}{\text{draft}_2} = \frac{drg_1}{dng_1} \times \frac{\dfrac{\text{oz. lap fed}_1 \times \text{doublings}}{\text{oz. lap delivered}_1}}{\dfrac{\text{oz. lap fed}_2 \times \text{doublings}}{\text{oz. lap delivered}_2}}.$$

But the oz. lap fed and doublings remain the same. Hence, we may simplify the right side by canceling, and we have:

$$(12)\quad \frac{drg_2}{dng_2} = \frac{drg_1}{dng_1} \times \frac{\text{oz. lap delivered}_2}{\text{oz. lap delivered}_1}.$$

EXAMPLE: *The finisher picker is delivering* 12.5-*oz. lap with a* 40-*tooth driver gear. We wish to increase our laps to* 14-*oz. What gears shall we put on?*

Using formula (12): $\frac{drg_2}{dng_2} = \frac{40}{50} \times \frac{14}{12.5} = .93. \quad \therefore drg_2 = .93 \times dng_2. \quad \therefore .93 \times dng_2 + dng_2 = 90. \quad \therefore dng_2 = \frac{90}{1.93} = 46.6.$

∴ driven gear must have 46 teeth and the driver gear must have 44 teeth.

To find the required draft gears when the draft constant, the ounce lap fed and the required ounce lap delivered are known:

From formula (9): $$\frac{drg}{dng} = \frac{dc}{\text{draft}} = \frac{dc}{\dfrac{\text{oz. lap fed} \times \text{doublings}}{\text{oz. lap delivered}}}.$$

Simplifying the right side:

$$(13)\quad \frac{drg}{dng} = \frac{dc \times \text{oz. lap delivered}}{\text{doublings} \times \text{oz. lap fed}}.$$

EXAMPLE: *Find the draft gears required to draft* 4 12-*oz. breaker laps to* $11\frac{1}{2}$-*oz. laps on a picker with a draft constant of* 4.00.

Using formula (13): $\frac{drg}{dng} = \frac{4.00 \times 11.5}{4 \times 12} = .958.$

∴ (see previous example) $dng = \frac{90}{1.958} = 45.9.$

∴ driven and driver draft gears each must have 45 teeth.

The following problems assume that the sum of the teeth of the draft gears equals 90. *Select the proper formula for each problem.*

33. If the draft constant is 4.50, what draft gears will draft 4 doublings of 12-oz. breaker lap to $11\frac{1}{2}$-oz. lap?

34. If a 42-tooth driven draft gear is inserting a draft of 3.6, what gears will insert a draft of 4.50?

35. A 42-tooth driver gear is delivering 12-oz. lap. We wish to make $13\frac{1}{2}$-oz. lap from the same breaker lap. What gear shall we use?

36. The usual number of doublings of 12.5-oz. breaker lap is drafted to 12-oz. lap on a picker with a constant of 4.68. What size draft gear shall we use?

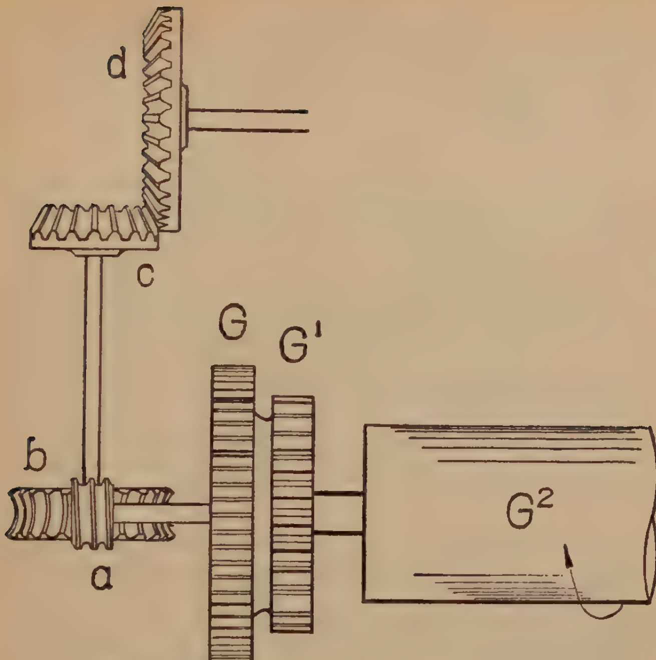
37. If a 40-tooth driver gear is delivering 14-oz. lap, what size driver gear will deliver 12-oz. lap from the same breaker lap?

38. A 36-tooth driver gear is inserting a draft of 4.24. What size driven gear will insert a draft of 3.68?

39. Make a diagram of the pulleys, belts and gears of an intermediate or finisher picker in your mill. Find the draft constant. Find out the weight of laps fed and delivered. Find out the percentage of waste. Determine the exact position of the cone belt. Then check the *mechanical* draft with the *actual* draft.

Length of Laps and Knock-off Constant

The knock-off motion gearing is shown in figure 3. G^2 of figure 2 is shown again in figure 3. Each time gear d makes one revolution, through appropriate mechanism it throws out the clutch shown between E and E^1 in figure 2, thus stopping the rolls at the delivery end of the machine. That is, while d makes one revolution the picker produces a roll of lap.



a—single worm.
b—worm knock-off change gear.
c—19 teeth.
d—31 teeth.
G^2—bottom calender roll 7 inches in diameter.

Figure 3. KNOCK-OFF MOTION OF PICKER SHOWN IN FIGURE 2

PROBLEMS:

40. From what you know of gears, revolutions and circumferences prove that:

$$\text{inches of lap passing over } G^2 = \frac{b \times d}{a \times c} \times \text{cir. } G^2 \times \text{revolutions of } d.$$

41. Also prove that during one revolution of *d*:

$$\text{yards of lap passing over } G^2 = \frac{b \times d \times \text{cir. } G^2}{36 \times a \times c}.$$

We know that during one revolution of d a full lap is produced and we know that the number of yards passing over G^2 is the number of yards of lap wound into the full lap roll.

42. Now prove that:

$$(14)\quad \frac{\text{yards in roll}}{b} = \frac{d \times \text{cir. } G^2}{36 \times a \times c}.$$

As will be seen from equation (14) the quotient of the yards in roll *divided* by the knock-off change gear is a constant. Hence, just as we have a draft constant we here have a *knock-off constant.*

43. Hence, letting *koc* stand for knock-off constant and *kog* stand for knock-off gear show that:

$$(15)\quad koc = \frac{\text{yds. in roll}}{kog} \text{ and also: } (16)\quad kog = \frac{\text{yds. in roll}}{koc}.$$

44. Using equation (14) and the figures in figure 3, find the knock-off constant of the picker in figures 2 and 3.

45. Using formula (16) and the value of the knock-off constant found in problem 44, find the knock-off gear required to make rolls of lap containing the following number of yards:
(*a*) 50 yards. (*b*) 36 yards. (*c*) 30 yards. (*d*) 60 yards.

Find the knock-off gear required on the picker in figures 2 and 3 to produce rolls containing:

46. 50 lbs. of 14-oz. lap.

47. 40 lbs. of 12-oz. lap.

48. 45 lbs. of 11.5-oz. lap.

49. Make a diagram of the knock-off gearing of a picker in your mill. Calculate the knock-off constant. Count the teeth in the knock-off gear. From the knock-off constant and knock-off gear calculate the number of yards that should be in the full lap. Find out the

oz. lap being made. From this *calculate* the weight of the full roll. Then determine the *actual* weight by weighing a full roll on the lap scales. How closely do the actual and calculated weights agree?

Production, Production Constants and Feed Pulleys of Intermediate or Finisher Pickers

50. As we did in equation (4) for the breaker picker and letting *pc* stand for production constant, work out the following formulas for 100% production in 10 hours of the intermediate picker in figure 2.

$$(17)\ \frac{\text{production}}{\text{oz. lap}\times\text{dia. }B^1\times\text{R.P.M. beater}}=\frac{25\times C^1\times D^1\times E^1\times F^1\times\text{cir. }V}{24\times\text{dia. }C\times D\times E\times F\times V^1}.$$

$$(17a)\ \text{production}=pc\times\text{oz. lap}\times\text{dia. feed pulley}\times\text{R.P.M. beater}.$$

$$(17b)\ \text{dia. feed pulley}=\frac{\text{production}}{pc\times\text{oz. lap}\times\text{R.P.M. beater}}.$$

51. Find the production constant of the intermediate picker in figure 2 equipped with combination 1.

52. Find the production of 10-oz. lap in 10 hours of the intermediate picker in figure 2 equipped with combination 1 and a 5-inch feed pulley if the speed of the beater is as shown, and allowing 10% loss of time for stoppages.

53. Find the pulley necessary to produce 2950 lbs. of 14-oz. lap on the picker in figure 2 equipped with combination 1 if the R.P.M. of the beater is as shown, and allowing 10% for stoppages.

54. A certain make of intermediate picker has a production constant of .0211. It produced 11,440 pounds of 12-oz. lap during a 55-hour week. What was its percent production if the speed of the beater is 1500 R.P.M. and the feed pulley is 6 inches in diameter?

R.P.M. of Feed Roll, Cage and Fan

55. Prove that:

$$(18)\ \text{R.P.M.}\ T = \frac{S^1 \times R^1 \times Q^1 \times C^2 \times \text{dia. } P^1 \times \text{dia. } B^1 \times \text{R.P.M. beater}}{T^1 \times S \times R \times P \times \text{dia. } Q \times \text{dia. } C}.$$

Find the R.P.M. of the feed roll, T, *in the picker in figure 2 equipped with the following combinations and the cone belt at normal position.*

56. Combination 1, 5-in. feed pulley, driver change gear 35 teeth.

57. Combination 2, 6-in. feed pulley, driver change gear 40 teeth.

58. Combination 4, 12-in. feed pulley, driver change gear 50 teeth.

59. Prove that:

$$(19)\ \underset{\text{cage}}{\text{R.P.M.}} = \frac{M^1 \times G^1 \times F^2 \times E^1 \times D^1 \times C^1 \times \text{dia. } B^1 \times \text{R.P.M. beater}}{O \times M \times G \times F \times E \times D \times \text{dia. } C}.$$

60. Find the speed of the cage of the picker in figure 2 with combination 1; gear M having 14 teeth; and the feed pulley being 5 inches in diameter.

61. Find the speed of the fan in figure 2 if B^2 is 6 inches in diameter and the fan pulley is 8 inches in diameter.

Beats per Inch and Feed Pulleys

62. As the breaker lap passes over the feed roll, T, the beater blades strike the cotton. It is evident that the length of cotton fed into the beater in a minute equals the surface speed of T. It is also evident that during this minute the two-blade beater in figure 2 will

strike this length of cotton 2 × 1450 blows. Now then work out the following formula:

$$(20)\quad \text{beats per inch} = \frac{\text{number of blades in beater} \times \text{R.P.M. beater}}{3.1416 \times \text{dia. feed roll} \times \text{R.P.M. feed roll}}.$$

EXAMPLE: *Find the beats per inch of the beater in figure* 2 *equipped with combination* 1; *a driver change gear of* 35 *teeth and a* 5-*inch feed pulley.*

In problem 56 we found with these conditions the R.P.M. of feed roll to be 3.086. Hence:

$$\text{beats per inch} = \frac{2 \times 1450}{3.1416 \times 3 \times 3.086} = 99.71.$$

63. Find the beats per inch in problem 57.

64. Find the beats per inch in problem 58.

Excessive and Insufficient Beats per Inch. There are certain limits for beats per inch. Too many beats per inch injure the cotton fiber; too few beats per inch fail to clean it. In the above example the beats per inch (99.71) are very high.

65. Suppose we wish to change the beats per inch, and it is not practical to change the overhead pulleys or *B*, the beater pulley, figure 2. Answer the following questions by referring to figure 2 and the equations indicated below:

(*a*) To change the beats per inch, what is the only quantity in equation (20) we can change?

(*b*) In order to change the R.P.M. of the feed roll, what is the only thing in equation (18) we can change without changing the draft as shown in equation (5)?

(*c*) Are the beats per inch directly or inversely proportional to the diameter of the feed pulley *B*? See equations (20) and (18).

(*d*) Are the beats per inch and production directly or inversely proportional?

66. Therefore, from problem 65 show that the following equation is true:

$$(21)\quad \text{dia. required feed pulley} = \frac{\text{present beats per inch} \times \text{dia. present feed pulley}}{\text{required beats per inch}}.$$

67. As shown in the preceding example, a 5-inch pulley gives practically 100 beats per inch. With the cotton we are running we do not wish to have over 60 beats per inch. What size pulley shall we use taking it for granted that we have every full-inch and half-inch size from 3 inches to 13 inches?

68. In problem 64 we wish to increase the beats per inch to not over 70. What size pulley must we use?

69. A picker with a feed roll 2 inches in diameter running 8 R.P.M., and a 3-blade beater running 1140 R.P.M., makes how many beats per inch on the cotton?

70. What will be the beats per inch on the cotton, if the 3-blade beater on a picker runs 1012 R.P.M. and the feed roll, 2 inches in diameter, runs 7 R.P.M.?

71. If the feed roll of a finisher picker is 2 inches in diameter and runs $6\frac{9}{10}$ R.P.M., and the 3-blade beater runs 1015 R.P.M., what number of beats per inch will the cotton receive?

72. If a finisher picker has a 3-blade beater running 1000 R.P.M., and the feed roll, 2 inches in diameter, running 7 R.P.M., how many beats per inch on the cotton?

73. From equation (20) prove that:

$$(22)\quad \text{R.P.M. beater} = \frac{3.1416 \times \text{dia. feed roll} \times \text{R.P.M. feed roll} \times \text{beats per inch}}{\text{number of blades in beater}}.$$

74. How many revolutions per minute will a 3-blade beater be required to run, if 69 beats per inch are required, the feed roll being 2 inches in diameter and running 7 R.P.M.?

75. With the feed roll of a picker 2 inches in diameter and running $7\frac{1}{2}$ R.P.M., how many revolutions per minute will a 3-blade beater be required to run to beat 68 beats per inch?

76. How many revolutions will a 3-blade beater be required to make per minute to beat 70 beats per inch, the feed roll being 2 inches in diameter and running 8 R.P.M.?

77. From the diagram which you have made of the intermediate picker in your mill, compute the production constant, the speeds of the feed roll, cage and fan and the beats per inch. Compute the production of the oz. lap being run and then check your computation with the production record of the picker.

CHAPTER VII

CARD CALCULATIONS

Draft

Figures 1 and 2 show the gearing of one make of card. Figure 1 shows a horizontal view of the card from the top. Figure 2 shows an upright view of the coiler from the main body of the card. Figure 2 is necessary to show the gearing between gears G and H^1 of figure 1.

As in all other machines, draft is figured from the back roll to the front or delivery roll. In the case of the card, therefore, draft is the ratio of the surface speed of the coiler calender roll I^2, to the surface speed of the lap roll, T^1.

The accompanying table, page 227, shows some of the gearing combinations of cards.

Problems:

1. In the same manner that the draft of the breaker picker was found, work out the following formula for card draft:

$$(1)\quad \text{draft} = \frac{T \times A^2 \times B^1 \times C^2 \times F^2 \times G^1 \times H^1 \times \text{dia. } I^2}{A^1 \times B \times C \times F \times G \times H \times I \times \text{dia. } T^1}.$$

2. Using formula (1) find the draft of the card in figure 1 equipped as shown in combination 1 of the accompanying table, and with the draft change gear B, having 30 teeth.

3. Find the draft of the card in problem 2 with a 10-tooth draft gear.

4. Find the draft of the card in figure 1 equipped with combination 2 and with a draft gear of 20 teeth.

5. Find the draft of the card in figure 1 equipped with combination 3 and with a draft gear of 14 teeth.

Some of the gear and pulley combinations of the card shown in figure 1 are set forth in the following table. In some makes of cards the licker-in pulley is furnished in varying sizes.

COMBINATION NUMBER	1	2	3
Diameter of I^2	2″	2″	2″
" " N^1	19″	19″	19″
" " O	7″	7″	7″
" " O^1	6″	6″	6″
" " P	9″	9″	9″
" " T^1	6″	6″	6″
Teeth in A^1	17	17	17
" " A^2	120	120	170
" " B (Note)	10 to 30	12 to 30	14 to 30
" " B^1	22	34	34
" " C	22	24	24
" " C^2	180	180	180
" " F	19	19	19
" " F^2	24	24	24
" " G	16	16	16
" " G^1	20	20	20
" " H	20	20	20
" " H^1	20	20	20
" " I	20	20	20
" " P^1	24	26	28
" " Q	104	104	104
" " Q^1 (Note)	17 to 40	17 to 40	17 to 40
" " T	48	48	48

NOTE: B is the draft change gear. Q^1 is the doffer change gear.

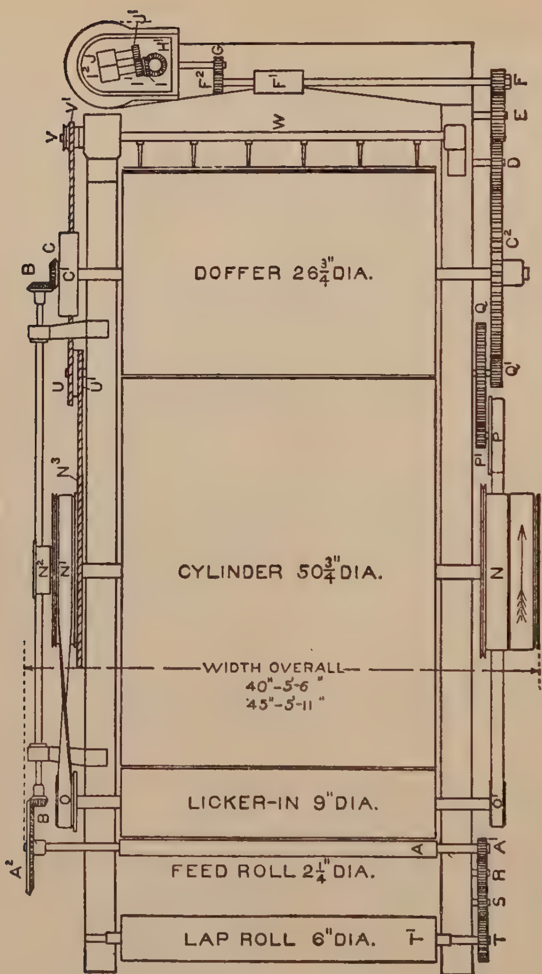


Figure 1. Gearing Diagram of a Card

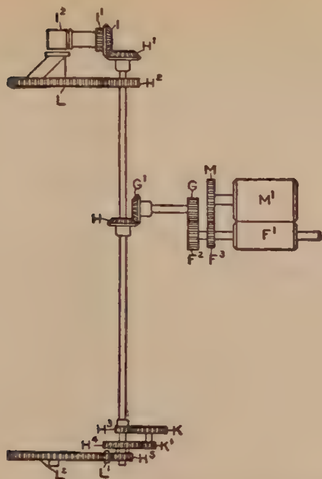


Figure 2. GEARING DIAGRAM OF A CARD COILER

DRAFT GEARS

6. From formula (1) prove that:

$$(2)\quad B = \frac{T \times A^2 \times B^1 \times C^2 \times F^2 \times G^1 \times H^1 \times \text{dia. } I^2}{A^1 \times B \times C \times F \times G \times H \times I \times \text{draft} \times \text{dia. } T^1}.$$

7. Answer the following questions by studying equation (2):

(*a*) Does increasing the number of teeth in the draft change gear increase or decrease the draft?

(*b*) Are the draft gear and draft directly or inversely proportional?

(*c*) Does the carding out of trash and waste tend to increase or decrease the draft as regards weight fed and weight delivered?

(*d*) Hence, in finding the draft gear should we drop the decimal or take the next highest whole number?

If the card in figure 1 *is equipped with combination* 1, *what draft change gears are required to insert the following drafts?*

8. 96. **9.** 112. **10.** 82.

Draft Constants

The use of *draft constants* in carding calculations greatly shortens the labor involved. From formula (2) and using the figures in combination (1) we have:

$$(3)\ \text{draft} \times B = \frac{T \times A^2 \times B^1 \times C^2 \times F^2 \times G^1 \times H^1 \times \text{dia. } I^2}{A^1 \times C \times F \times G \times H \times I \times \text{dia. } T^1}$$
$$= \frac{48 \times 120 \times 22 \times 180 \times 24 \times 20 \times 20 \times 2}{17 \times 22 \times 19 \times 16 \times 20 \times 20 \times 6}$$
$$= 1604.95.$$

It is thus seen that regardless of the draft and the size of the draft gear the *product* of the draft and draft gear always equals a fixed number as long as the other gears and rolls remain unchanged. This fixed number is called the *draft constant*. Hence, the draft constant of the card in figure 1 equipped with combination 1 is 1604.95. Letting *dc* stand for draft constant and *dg* stand for draft change gear we have the following formulas:

$$(4)\ dc = \text{draft} \times dg. \qquad (5)\ dg = \frac{dc}{\text{draft}}. \qquad (6)\ \text{draft} = \frac{dc}{dg}.$$

EXAMPLE: *The draft constant of the card equipped with combination* 1 *is, as shown above,* 1604.95. *What draft gear will insert a draft of* 100?

Using formula (5): $dg = \frac{dc}{\text{draft}} = \frac{1604.95}{100} = 16.05.$ Answer: 16 teeth.

If the card in figure 1 *is equipped with combination* 1 *find the draft gear required to insert a draft of:*

11. 96. **12.** 112. **13.** 82. **14.** 92. **15.** 60.5.

Find the draft gear required in the following cases:

16. Draft constant is 2373.90, draft required is 121.5.

17. Draft constant is 3221.05, draft required is 132.6.

EXAMPLE: *If the card in figure* 1 *is equipped with combination* 1 *find the draft inserted by a gear of* 20 *teeth.*

Using equation (6): draft $= \frac{dc}{dg} = \frac{1604.95}{20} = 80.24$.

If the card in figure 1 *is equipped with combination* 1, *what drafts will be inserted by the following draft gears?*

18. 10-tooth. **19.** 18-tooth. **20.** 28-tooth.

Find the draft inserted in the following cases:

21. Draft constant is 2373.90. Draft gear has 15 teeth.

22. Draft constant is 3221.05. Draft gear has 29 teeth.

EXAMPLE: *By weighing the lap fed into the card and the sliver delivered we find that the card has an actual draft of* 112.5 *with a* 15*-tooth draft gear. What is the approximate or actual draft constant?*

Using equation (4): draft constant = draft $\times$ draft gear = $112.5 \times 15 = 1687.5$.

23. Answer the following questions:

(*a*) Does the removal of short fiber, neps and motes by the card cause the *actual* draft found by weighing to be greater or less than the *mechanical* draft? Why?

(*b*) Does the removal of the preceding material by the card cause the actual draft found by *weighing* to be greater or less than the actual draft found by *measuring* lengths? Why?

(*c*) Will the *actual* or approximate draft constant based on weight fed and weight delivered be greater or less than the draft constant? Why?

Find the actual draft constant in the following cases:

24. A draft of 121.6 is being inserted by a 13-tooth draft gear.

25. A draft of 112.4 is being inserted by a 15-tooth draft gear.

26. 14-oz. lap is drafted into 61-grain sliver by a 17-tooth draft gear.

27. $10\frac{1}{2}$-oz. lap is drafted into 48-grain sliver by a 20-tooth draft gear.

The only way in which the draft constant can be found exactly is by calculating from the gears and rolls as we did in equation (3).

28. Find the draft constant of the card in figure 1 equipped with combination 2.

29. Find the draft constant of the card in figure 1 equipped with combination 3.

Combinations of Card Draft Formulas

In exactly the same manner that the combination intermediate picker draft formulas number (11), (12) *and* (13) *were made, and letting* dg *stand for draft gear and sub-one* ($_1$) *for "present" and sub-two* ($_2$) *for "required," work out the following formulas:*

30. (7) $dg_2 = \dfrac{dg_1 \times \text{draft}_1}{\text{draft}_2}.$

31. (8) $dg_2 = \dfrac{dg_1 \times \text{gr. sliver}_2}{\text{gr. sliver}_1}$

when the oz. lap fed remains unchanged.

32. (9) $dg = \dfrac{dc \times \text{gr. sliver}}{437.5 \times \text{oz. lap}}.$

33. Also in the same manner that you worked out formula (8) work out:

$$(10)\ dg_2 = \frac{dg_1 \times \text{oz. lap}_1 \times \text{gr. sliver}_2}{\text{oz. lap}_2 \times \text{gr. sliver}_1}$$

when the oz. lap is to be changed.

Select the proper formula and solve the following:

34. A card now has a draft of 116.6 with a 14-tooth draft gear. We wish to reduce the draft to 102.4. What gear shall we use?

35. A 16-tooth gear is now producing 60-gr. sliver. Without changing the oz. lap we must produce 42-gr. sliver. What gear shall we use?

36. We wish to draft 13.5-oz lap into 52-gr. sliver on a card with a constant of 1604.00. What gear shall we use?

37. 14.5-oz. lap is now being drafted into 60-gr. sliver with a 16-tooth gear. On the same card we wish to draft 12-oz. lap into 48-gr. sliver. What tooth gear shall we use?

38. 54-gr. sliver is produced by a card with an 18-tooth gear. What gear will produce 60-gr. sliver from the same lap?

39. If the constant of a card is 2273.64, what gear will draft 11.36-oz. lap into 55-gr. sliver?

40. What gear will insert a draft of 102 if a 20-tooth gear inserts a draft of 80?

41. 54-gr. sliver is being drafted from 13.5-oz. lap with a 24-tooth draft gear. What gear will draft 12.5-oz. lap into 62-gr. sliver?

R.P.M. of Doffer and Doffer Change Gears

42. Work out the following formula:

$$(11)\ \text{R.P.M. doffer} = \frac{P^1 \times Q^1 \times \text{dia. } N^1 \times \text{dia. } O^1 \times \text{R.P.M. cylinder}}{Q \times C^2 \times \text{dia. } O \times \text{dia. } P}.$$

Find the R.P.M. of the doffer of the card in figure 1 equipped with the following combinations and the cylinder making 165 R.P.M.

43. Combination 1 and a 20-tooth doffer change gear.

44. Combination 1 and a 40-tooth doffer change gear.

45. Combination 2 and an 18-tooth doffer change gear.

46. Combination 3 and a 30-tooth doffer change gear.

47. Work out from formula (11) the following formula:

$$(12)\quad Q^2 = \frac{Q \times C^2 \times \text{dia. } O \times \text{dia. } P \times \text{R.P.M. doffer}}{P^2 \times \text{dia. } N^2 \times \text{dia. } O^2 \times \text{R.P.M. cylinder}}.$$

What change gear with the following combinations and with a cylinder R.P.M. of 165 will give a doffer speed of:

48. 12 R.P.M. with combination 1.

49. 8.25 R.P.M. with combination 2.

50. 9.5 R.P.M. with combination 3.

Production, Production Constants and Doffer Change Gears

51. Work out the following equation:

$$\text{R.P.M. } I^2 = \frac{H^2 \times G^2 \times F^2 \times C^2 \times \text{R.P.M. doffer}}{I \times H \times G \times F}.$$

52. From problem 51 work out the following equation:

$$\text{S.S. } I^2 = \frac{H^2 \times G^2 \times F^2 \times C^2 \times \text{R.P.M. doffer} \times \text{cir. } I^2}{I \times H \times G \times F}.$$

53. As was done in the case of the breaker picker, work out the following equation for 100% production in lbs. for 10 hours.

$$\text{production} = \frac{\text{gr. sliver} \times 600 \times H^2 \times G^2 \times F^2 \times C^2 \times \text{R.P.M. doffer} \times \text{cir. } I^2}{36 \times 7000 \times I \times H \times G \times F}.$$

54. Then letting *pc* stand for production constant show that:

$$(13)\quad \frac{\text{production}}{\text{gr. sliver} \times \text{R.P.M. doffer}} = \frac{H^1 \times G^1 \times F^2 \times C^2 \times \text{cir. } I^2}{420 \times I \times H \times G \times F} = pc.$$

$$(14)\quad \text{production} = pc \times \text{gr. sliver} \times \text{R.P.M. doffer}.$$

55. Using formula (13) find the production constant of the card in figure 1.

56. Find the production constant on a certain make of card if C^2 has 214 teeth, F 21, G^1 23, H 17, H^1 21, I 18 teeth, and F and G^1 are on the same shaft, and I^2 is 2 inches in dia.

EXAMPLE: *If the doffer in figure 1 has a speed of 12.25 R.P.M., how many pounds of 60-grain sliver will it produce in 10 hours if 5% loss of time is allowed for stripping, oiling, etc.?*

Using formula (13) and the production constant found in problem 55: production = .213 × 60 × 12.25 = 156 lbs. 95% of 156 lbs. = 148 lbs.

57. Find the production of 55-gr. sliver by the card in figure 1 if the doffer makes 14 R.P.M. allowing 5% loss.

58. Find the production of the card in problem 47 of 50-gr. sliver in 10 hrs. if the doffer makes 10 R.P.M. allowing 5% loss.

59. The production constant of a card is .219. How many pounds of 56-gr. sliver will it produce in 10 hrs. if its doffer runs 12 R.P.M. allowing 5% loss?

60. The production constant of a card is .182. How many pounds of 46-gr. sliver will it produce if the doffer makes 13 R.P.M. allowing 5% loss?

61. 32 cards each with a production constant of .182 and each having a doffer speed of 13 R.P.M. produce

3200 lbs. of 44-gr. sliver in 10 hrs. What percent production is being gotten out of these cards?

62. What percent production must be attained by 24 cards each with a production constant of .182 and a doffer speed of 12 R.P.M. to produce 3025 lbs. of 50-gr. sliver in 10 hrs.?

63. Allowing 5% loss find the difference in the productions for 10 hours of two cards each having a production constant of .219 and a doffer speed of 13 R.P.M., one card making 52-grain sliver and the other making 48-grain sliver.

64. With the grade of cotton we are about to run and for the grade of work our mill is running after allowing 5% loss we should get a production of 126 lbs. of 50-grain sliver a day from the card in figure 1 equipped with combination 3. What size doffer change gear must we use to obtain this production if the cylinder makes 165 R.P.M.?

65. From formulas (11) and (14), and giving ($_1$) and ($_2$) their usual meanings, work out the following formulas:

$$(15)\ \text{doffer change gear}_2 = \frac{\text{doffer change gear}_1 \times \text{gr. sliver}_1 \times \text{production}_2}{\text{gr. sliver}_2 \times \text{production}_1}.$$

66. A card has been producing 127 lbs. of 40-gr. sliver in 10 hrs. with a 24-tooth doffer change gear. What doffer gear will give the same production of 48-gr. sliver?

67. A card with a 21-tooth doffer gear has been producing 54-gr. sliver. What gear will give the same production of 42-gr. sliver?

68. Out of a certain card we have been getting a production of 117 lbs. in 10 hrs. with a 17-tooth doffer gear. What gear will give a production of 124 lbs. of the same sliver in 10 hrs.?

69. For obvious reasons the doffer gear is sometimes called the production gear. A card has been producing 148 lbs. a day of 56-gr. sliver with a 20-tooth production gear. What production gear will produce 164 lbs. a day of 40-gr. sliver?

Speed of the Licker-in

70. The licker-in pulley, *O*, is sometimes changed. Calculate the R.P.M. of the licker-in of the card in figure 1 if the cylinder makes 165 R.P.M.

71. (*a*) Would a change in the diameter of the licker-in pulley affect the draft?

(*b*) Would a change in the licker-in pulley affect the production constant?

(*c*) Is the diameter of the licker-in pulley directly or inversely proportional to the production?

CHAPTER VIII

DRAWING FRAME CALCULATIONS

TOTAL DRAFT, DRAFT CHANGE GEARS AND DRAFT CONSTANTS

Figure 1 represents the gearing of a drawing frame equipped with an electric stop motion. The following table shows two of many possible gearing combinations of a drawing frame. Gears O and P are fast on the same shaft. O, through the carrier, or intermediate, gear, runs R. Q, which is on the end of the calender roll shaft, is run by P. K is the draft change gear. J, the back roll change gear, can be changed to make large changes in draft. On this machine *total draft* is figured between the electric lifting roll and the calender roll. Without a lifting roll total draft would be figured between the back roll and calender roll. Metallic rolls will be discussed later.

PROBLEMS: *The following problems refer to common rolls.*

1. Work out a formula for the draft constant of the frame in figure 1 similar to formula (3) for the card.

2. Find the draft constant of the frame in figure 1 equipped with a 48-tooth back roll change gear.

3. Find the draft constant of the frame in figure 2 equipped with a 68-tooth back roll change gear.

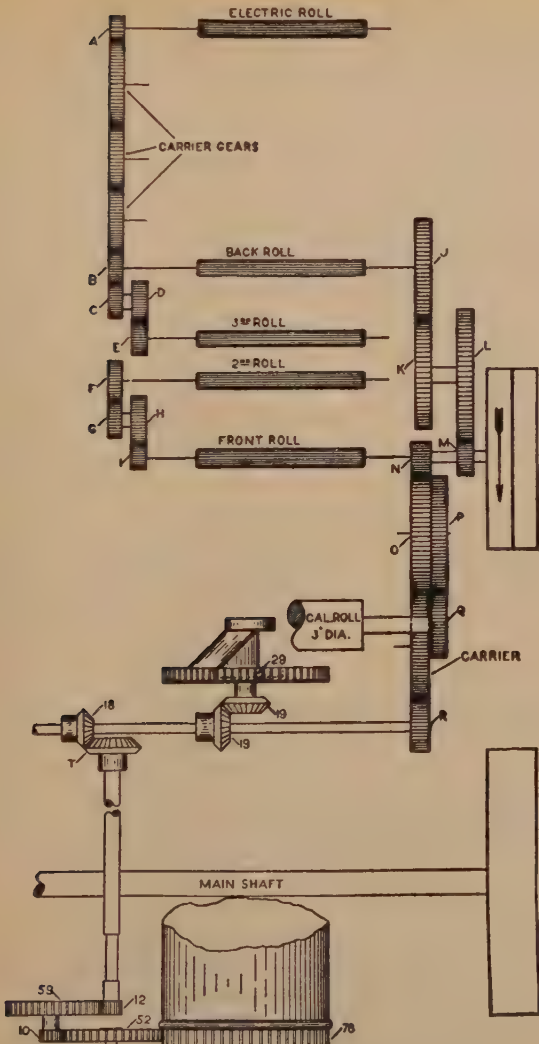


Figure 1. - GEARING OF DRAWING FRAME

Combination Number	1 Common Rolls	2 Metallic Rolls
Diameter Electric Roll	$1\frac{1}{8}''$	$1\frac{1}{8}''$
" Back Roll	$1\frac{1}{8}''$	$1\frac{1}{8}''$ 16 Pitch
" 3rd Roll	$1\frac{1}{8}''$	$1\frac{1}{8}''$ 24 "
" 2nd Roll	$1\frac{1}{8}''$	$1\frac{1}{8}''$ 32 "
" Front Roll	$1\frac{3}{8}''$	$1\frac{3}{8}''$ 32 "
" Calender Roll	3″	3″
Teeth in *A*	24	20
" " *B*	24	29
" " *C*	36	31
" " *D*	40	36
" " *E*	24	24
" " *F*	34 or 36	33
" " *G*	24	28
" " *H*	40	40
" " *I*	20	20
" " *J*	48 or 68	66
" " *K*	45 to 70	45 to 70
" " *L*	98	98
" " *M*	22	22
" " *N*	16	19
" " *O*	52	52
" " *P*	91	91
" " *Q*	59	53

On this frame draft change gears of less than 45 teeth are not used.

Approximate Metallic Roll Equivalents:

16 Pitch $1\frac{1}{8}''$ Metallic Roll = $1\frac{3}{8}''$ Common Roll.
24 " $1\frac{1}{8}''$ " " = $1\frac{1}{4}''$ " "
32 " $1\frac{1}{8}''$ " " = $1\frac{1}{4}''$ " "
32 " $1\frac{3}{8}''$ " " = $1\frac{5}{8}''$ " "

4. Work out the following formulas:

(1) draft constant = draft × draft gear.

(2) $$\text{draft gear} = \frac{\text{draft constant}}{\text{draft}}.$$

(3) $$\text{draft} = \frac{\text{draft constant}}{\text{draft gear}}.$$

5. (*a*) If the frame in figure 1 is equipped with a 48-tooth back roll change gear, what is the largest draft that can be obtained with the draft change gears shown in the table?

(*b*) If the frame is equipped with a 68-tooth back roll change gear, what is the largest draft that can be obtained with the draft change gears shown in the table?

(*c*) Why have a gear on the back roll that can be changed?

6. If the frame in figure 1 has on a 48-tooth back roll gear, what draft gear will insert a draft of 5.8?

7. A certain frame is inserting a draft of 6.98 with a draft gear of 32 teeth. What is the draft constant of the frame?

8. Work out the following formulas, letting sub-one ($_1$) mean "present" and sub-two ($_2$) mean "required," and *dg* and *dc* stand for draft gear and draft constant. It is understood that 6 doublings are fed.

(4) $dg_2 = \dfrac{dg_1 \times \text{draft}_1}{\text{draft}_2}$.

(5) $dg_2 = \dfrac{dg_1 \times \text{grain sliver fed}_1 \times \text{grain sliver delivered}_2}{\text{grain sliver delivered}_1 \times \text{grain sliver fed}_2}$ when changing both the grain sliver fed and delivered.

(6) $dg_2 = \dfrac{dg_1 \times \text{gr. sliver delivered}_2}{\text{gr. sliver delivered}_1}$ when changing the grain sliver delivered from the same weight of sliver fed.

(7) $dg_2 = \dfrac{dg_1 \times \text{gr. sliver fed}_1}{\text{gr. sliver fed}_2}$ when changing the grain sliver fed into the same weight of sliver delivered.

(8) $dg = \dfrac{dc \times \text{gr. sliver delivered}}{6 \times \text{gr. sliver fed}}$.

9. A draft gear of 40 teeth has been inserting a draft of 7.1. What gear will insert a draft of 6.4?

10. 62-gr. sliver is being produced with a draft gear of 41 teeth. What gear will produce 54-gr. sliver from the same weight sliver now being fed?

11. We must make 52.5-gr. sliver from 51-gr. sliver on a frame with a draft constant of 258.74. What draft gear shall we put on?

12. A certain frame with a 56-tooth draft gear is drawing 44-gr. sliver into 46-gr. sliver. On the same machine we wish to change to drawing 46-gr. sliver into 52-gr. sliver. What gear shall we use?

13. On the frame in figure 1 with a 48-tooth back roll gear we have been drafting 50.2-gr. sliver into 51.3-gr. sliver. We must now draft the same sliver fed into 46-gr. sliver. What gears shall we use?

14. 62-gr. sliver is being fed. We wish to change the draft so that 56-gr. sliver will be drawn into the same weight sliver as before. By how many teeth shall we increase the draft gear if the draft gear now on has 46 teeth?

Intermediate Drafts

The drafts between successive rolls are called *intermediate drafts*. The intermediate draft between two successive rolls not directly connected is called *break draft*. The break draft in figure 1 is between the 2nd and 3rd rolls.

What is the intermediate draft between the following rolls in figure 1:

15. The electric roll and the back roll?

16. The back roll and the 3rd roll?

17. The 3rd roll and the 2nd roll if F has 34 teeth, K 49 teeth and J 48 teeth?

18. The 2nd roll and the front roll if F has 34 teeth?

19. The front roll and the calender roll?

20. Find the *product* of the above intermediate drafts. Find the total draft from the draft constant. The *product* of the *intermediate* drafts must equal the *total* draft.

21. Find the intermediate draft between the 2nd roll and the front roll if F has 36 teeth.

22. Answer the following questions:

(*a*) A change in the draft gear changes the draft between which successive rolls? What is this draft called?

(*b*) What effect does a change in F have on the total draft?

(*c*) If the limit of total draft of the frame is increased by increasing the back roll change gear, would you increase or decrease gear F? Why?

Metallic Rolls

Metallic rolls are measured like common rolls. But because they mesh like gears their *effective* circumferences are greater than their real circumferences. Like gears they are known by their pitch. The preceding table shows their effective diameters. In general, a 16-pitch metallic roll has an effective diameter 50% greater than its real diameter; a 24 and 32-pitch roll has an effective diameter 33% larger than its real diameter.

23. Reason out the answers to the following as you think of the sliver going between the meshing rolls:

(*a*) Why is the effective diameter of a 16-pitch roll greater than the effective diameter of a 32-pitch roll of the same size?

(*b*) Why is the effective diameter of a 24-pitch roll the same as the effective diameter of a 32-pitch roll of the same size?

(*c*) When drafting a thick heavy sliver, is the effective diameter of a metallic roll less or greater than when drafting a thin light sliver?

(*d*) Would a thick sliver decrease the effective diameter of a 16-pitch roll as much as it would decrease the effective diameter of a 32-pitch roll? Why?

(*e*) Then what is the idea of increasing the pitch of the rolls as the sliver travels toward the front?

The electric lifting rolls do not mesh, neither do the calender rolls.

24. Reason out the following questions:

(*a*) Will the sliver pass between two metallic rolls faster or slower than it would pass between two common rolls of the same size and making the same R.P.M.?

(*b*) Therefore explain why gears N and Q for metallic rolls differ from common. Also explain the reason for the difference in gears A and B for common and for metallic rolls.

(*c*) For the same R.P.M. and size of rolls will a frame with metallic rolls have a greater or less production per day than one with common rolls?

For the reasons which you thought out in problem 23 the *mechanical* draft and the *actual* draft of metallic rolls may differ considerably due to the weight of sliver fed, etc.

25. Find the draft constant for the frame in figure 1 equipped with metallic rolls as shown in the table.

Production and Production Constants

26. Work out the following formulas of the production constant of the drawing frame in figure 1 based

upon 10 hours a day for one delivery of the frame. Refer to the manner in which these were worked out for the picker and card.

(9) $pc = \frac{\text{production}}{\text{gr. sliver} \times \text{R.P.M. front roll}} = \frac{P \times N \times \text{cir. calender roll}}{420 \times Q \times O}.$

(10) production $= pc \times$ gr. sliver $\times$ R.P.M. front roll.

27. Find the production constant of the frame in figure 1 equipped with common rolls.

28. Find the production constant of the frame in figure 1 equipped with metallic rolls.

29. Find the production of 60-gr. sliver of each delivery of the frame in figure 1 equipped with common rolls if the front roll makes 350 R.P.M. Allow 20% loss due to cleaning, oiling, doffing, etc.

30. If the frame in figure 1 is equipped with metallic rolls and the front roll makes 350 R.P.M., how many pounds of 60-gr. sliver will each delivery of the frame produce in a day, allowing 20% loss?

31. What percent greater is the production of the frame in figure 1 when equipped with metallic rolls than when equipped with common rolls?

32. Here is a rule for production of a common roll frame for 10 hours that is sometimes used:

"Multiply the R.P.M. of the front roll by the circumference of the front roll by the gr. sliver being produced by the number of deliveries of the frame by 600; and divide this product by the product of 36 by 7000."

(*a*) By using this rule calculate the production of 50-gr. sliver of the frame in figure 1 equipped with common rolls if the front roll makes 400 R.P.M. and the frame has 15 deliveries, allowing 20% loss.

(*b*) Calculate the production of the same frame under the same conditions using the production constant, allowing 20% loss.

(*c*) How much in error is the preceding rule:

1. In pounds per day?
2. In percent taking the result in (*b*) preceding as 100%?

(*d*) Where is the error in the rule?

33. Two frames exactly similar to the one in figure 1 equipped with metallic rolls, each frame having 2 heads of 6 deliveries in each head, are producing 6000 lbs. of 55-gr. sliver in a 10-hour day. If the front roll makes 400 R.P.M., what percent production is being obtained?

CHAPTER IX

FLY FRAME CALCULATIONS

The slubber, intermediate, speeder and jack fly frames are constructed similarly. Figure 1 represents the gearing of a slubber.

DRAFT

Draft on a fly frame is figured between the back roll f_3 and the front roll f_1.

PROBLEMS:

1. In the same manner that the draft constant was found on the machine previously studied, find the draft constant of the slubber in figure 1.

2. Work out three formulas: for finding the draft gear from the draft and draft constant; for finding the draft from the draft gear and draft constant; and for finding the draft constant from the draft and draft gear.

Because of the twist inserted by fly frames the roving contracts after it leaves the front roll. Therefore, when using the draft constant found as in problem 1 it is necessary to allow for contraction of draft. In the following problems allow 3%.

3. What draft gear on the frame in figure 1 will insert a draft of 5?

4. What draft on the frame in figure 1 will be inserted by a draft gear of 40 teeth?

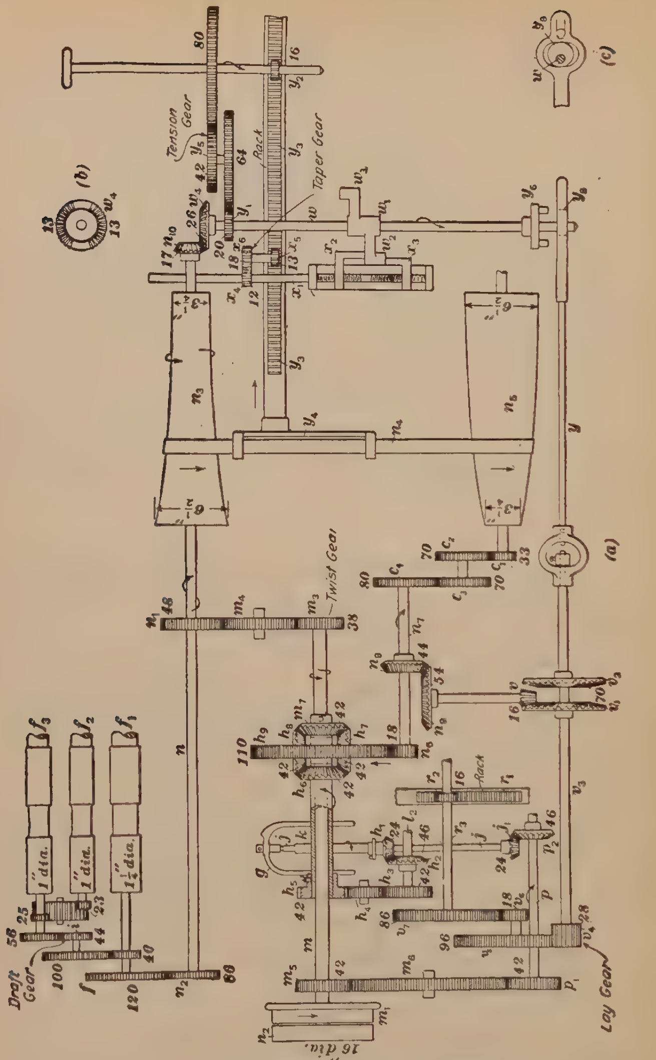


Figure 1. Gearing of a Fly Frame
(Courtesy and special permission of the International Textbook Co.)

5. If we find the *actual* draft constant from the *actual* draft and the draft gear used, need we later when using this *actual* draft constant make any allowance for contraction? Why?

6. A 54-tooth draft gear is inserting an actual draft of 3.535. What is the actual *draft* constant?

7. On the frame in problem 6, what draft gear will insert a draft of 4.42?

EXAMPLE: *What gear will draft* 60-*gr. sliver into* .60-*hank roving if the* actual *draft constant of the slubber is* 202?

From formula (4), chapter III:

$$\text{draft} = \frac{12 \times \text{gr. sliver} \times \text{hank roving}}{100} = \frac{12 \times 60 \times .60}{100} = 4.32.$$

$$\text{Therefore: draft gear} = \frac{202}{4.32} = 46.7.$$

8. What size gear is required to draft 65-gr. sliver into .55-hank roving on a frame with an *actual* draft constant of 173.02?

9. If the draft constant on an intermediate frame is 190, what gear will draft .50-hank roving doubled into 1.25-hank roving?

10. The actual draft constant on a speeder frame is 170.27. What gear will draft 1.40-hank roving doubled into 4-hank roving?

11. Using one of the formulas worked out in problem 2, work out the following formula:—*Hint:* Refer to how the similar formula was worked out for the intermediate picker. Let sub-one ($_1$) mean "present" and sub-two ($_2$) mean "required."

$$(1)\ dg_2 = \frac{dg_1 \times \text{draft}_1}{\text{draft}_2}.$$

From formula (1) *and from the appropriate formulas in the chapter on actual draft, work out the following formulas:*

12. For slubber when changing the gr. sliver and hank roving:

$$(2)\ dg_2 = \frac{dg_1 \times \text{hank roving}_1 \times \text{gr. sliver}_1}{\text{hank roving}_2 \times \text{gr. sliver}_2}.$$

13. (*a*) For slubber when changing hank roving delivered from same gr. sliver fed:

$$(3)\ dg_2 = \frac{dg_1 \times \text{hank roving}_1}{\text{hank roving}_2}.$$

(*b*) For slubber when producing same hank roving from a different gr. sliver:

$$(4)\ dg_2 = \frac{dg_1 \times \text{gr. sliver}_1}{\text{gr. sliver}_2}.$$

14. For intermediate, speeder and jack frames when changing hank roving delivered and hank roving fed with same doublings:

$$(5)\ dg_2 = \frac{dg_1 \times \text{hank roving delivered}_1 \times \text{hank roving fed}_2}{\text{hank roving delivered}_2 \times \text{hank roving fed}_1}.$$

15. (*a*) For intermediate, speeder and jack frames when changing hank roving delivered from same hank roving fed with same doublings:

$$(6)\ dg_2 = \frac{dg_1 \times \text{hank roving delivered}_1}{\text{hank roving delivered}_2}.$$

(*b*) For intermediate, roving and jack frames when producing same hank roving from a different hank roving fed but with same doublings:

$$(7)\ dg_2 = \frac{dg_1 \times \text{hank roving fed}_2}{\text{hank roving fed}_1}.$$

16. For all fly frames when changing *weight* per yard delivered from same weight per yard fed from same doublings:

(8) $dg_2 = \dfrac{dg_1 \times \text{weight in grs. of a certain length delivered}_2}{\text{weight in grs. of the same length delivered}_1}$.

17. In using any of the formulas from (1) to (8) need we make an allowance for contraction in draft? Why?

18. With a 30-tooth draft gear a slubber is producing .50-hank roving from 70-gr. sliver. What gear will produce .45-hank roving from 65-gr. sliver?

19. 12 yards of hank roving delivered by a fly frame weigh 120 grs. What gear shall we use to increase this to 133 grs. if the gear now on the frame has 35 teeth?

20. Using a 42-tooth draft gear a fly frame is producing 1.36-hank roving from .54-hank roving. What gear will produce 1.28-hank roving from .56-hank roving?

21. A draft gear with 30 teeth is drafting 52.8-gr. sliver into the same hank roving which we now wish to draft from 48-gr. sliver. What gear shall we use?

22. The desired hank roving is being produced by a draft gear with 36 teeth from 2.4-hank roving. What gear will produce the same hank roving from 2.64-hank roving?

23. What is the draft between the back and middle rolls of the slubber in figure 1?

24. What is the break draft of figure 1 if the draft gear has 44 teeth?

25. Multiply the intermediate drafts together and compare with total draft found by using the draft constant.

Twists per Inch, Twist Gears and Twist Constants

It is evident from figure 1 that the flyer, g, being driven by ordinary spur and bevel gears, m_5, m_6, p_1, p_2 and j_1, and having its shaft, j, independent of the bobbin, k, travels at an unvarying speed.

It is also evident that the front roll, f_1, being driven by the main shaft, which runs through the differential from m_5 to m_3, runs at an unvarying speed.

We know that the surface speed of the front roll in inches per minute equals the length of cotton delivered by the front roll per minute. We also know that the number of twists put into the roving per minute equals the R.P.M. of the flyer. Therefore, letting *tpi* stand for twists per inch:

26. Show that:

$$(9)\ tpi = \frac{\text{R.P.M. } g}{\text{R.P.M. } f_1 \times \text{cir. } f_1}.$$

27. Now from what you know of gear trains and using equation (9), work out the following formula:

$$(10)\ tpi \times m_3 = \frac{p_2 \times m_5 \times n_1 \times f}{j_1 \times p_1 \times n_2 \times \text{cir. } f_1}.$$ This formula gives the *twist constant* of the fly frame in figure 1.

28. Using formula (10) and the sizes shown in figure 1, compute the twist constant of this frame.

29. From equation (10) work out the following formulas, letting *tc* stand for twist constant and *tg* for twist change gear:

$$(11)\ tc = tg \times tpi. \qquad (12)\ tg = \frac{tc}{tpi}. \qquad (13)\ tpi = \frac{tc}{tg}.$$

EXAMPLE: *What twist gear on the frame in figure* 1 *will insert the proper twist in .50-hank roving?*

The proper *tpi* for .50-hank roving $= 1.2 \times \sqrt{.50} = 1.2 \times .707 = .85$.

Using equation (12): desired twist gear $= \dfrac{32.69}{.85} = 38.5$.

Answer: 39-tooth twist gear.

In the following problems 1.2 is considered the twist multiplier.

30. (*a*) Are the twists per inch and the number of teeth in the twist gear directly or inversely proportional?

(*b*) What effect does the contraction due to twisting have upon the number of twists per inch? Therefore:

(*c*) In finding the twist gear, should we drop the decimal or use the next higher whole number? Why?

31. What gear will insert the proper twist in .80-hank roving if the twist constant of the frame is 44?

32. If 2.68 twists per inch are being inserted with a 47-tooth twist gear, what is the *actual* twist constant of the frame?

33. (*a*) If the contraction due to twisting is 3%, by how many twists per inch does the twisting increase the twists in one inch of 6-hank roving?

(*b*) Therefore, on fly frames need we make any distinction between the *actual* twist constant and the twist constant?

34. If the twist constant of a frame is 62, what twist per inch will a 32-twist gear insert?

Letting sub-one ($_1$) *mean "present" and sub-two* ($_2$) *mean "required," by using formula* (11) *work out the following formulas:*

35. When changing twists per inch:

$$(14)\quad tg_2 = \frac{tg_1 \times tpi_1}{tpi_2}, \text{ and therefore:}$$

36. When changing hank roving:

$$(15)\quad tg_2 = \frac{tg_1 \times \sqrt{\text{hank roving}_1}}{\sqrt{\text{hank roving}_2}}.$$

EXAMPLE: *A speeder frame is inserting* 2.7 *twists per inch with a 23-tooth twist gear. What gear will insert* 2.3 *twists per inch?*

Using equation (14): $tg_2 = \frac{23 \times 2.7}{2.3} = 27$. Answer: 27-tooth twist gear.

EXAMPLE: *A slubber is inserting the proper twist in* .40-*hank roving. What gear must we use for* .65-*hank roving, if the present gear has* 66 *teeth?*

Using equation (15): $tg_2 = \frac{66 \times \sqrt{.40}}{\sqrt{.65}} = \frac{66 \times .632}{.806} = 51.7$.
Answer: 52-tooth twist gear.

37. If a 48-tooth gear is inserting 1 twist per inch, what gear will insert 1.2 twists per inch?

38. If a 36-tooth gear is inserting the proper twist in 5.10-hank roving, what gear shall we use for 4.4-hank roving?

39. What twist gear shall we use for 1.4-hank roving if a 32-tooth gear inserts the proper twist in 1.56-hank roving?

LAPS PER INCH, LAY GEARS AND LAY CONSTANTS

The rack, r_1, in figure 1 moves the bobbins up and down as the bobbin winds the roving onto itself. The bobbin must move up and down in such a manner that

the coils or laps of roving will lie closely and evenly upon the bobbin. From our study of roving diameters in chapter IV we know that a considerable change in the hank roving being made by the frame would make the coils of roving either overlap or have gaps between them if the speed at which the bobbin moves up and down could not be changed in accordance with the diameter of the roving being made. This change is made by changing the lay change gear, v_4.

Another change in the speed of the rack, r_1, is made automatically by the automatic shifting of the cone belt, n_4. As each layer of roving is wound on the bobbin the cone belt is shifted automatically toward the small end of the driving cone, n_3, thereby decreasing the additional R.P.M. that the bobbin receives through the differential center gear, h_9, and thereby decreasing the difference between the R.P.M. of the bobbin and the flyer. It is this excess R.P.M. of the bobbin over the flyer that causes the bobbin to coil the roving onto itself. Hence, the decreasing of this excess R.P.M. of the bobbin as the circumference of the bobbin increases keeps the *excess* surface speed of the bobbin constant and enables the bobbin to coil the roving at the constant rate that it is delivered by the front roll, *f*. Since the excess surface speed of the bobbin over the flyer is constant, and at each layer its diameter is larger, a longer time is required to wind a coil of roving in each succeeding layer. Therefore, the rack must move up and down slower at each succeeding layer. It will be seen that the rack receives its motion from the bottom cone. Therefore, as the R.P.M. of the bobbin decreases, the speed of the rack decreases.

In figure 1 the rack is shown as rising. As soon as the rack reaches the top and finishes one layer the shaft v_3 will automatically be "kicked" to the left, gear v_2 instead of v_1 will mesh with v, thereby reversing the direction of the rack.

At each excess revolution of the bobbin over the flyer it winds one coil or lap upon itself. Therefore, the excess R.P.M. of the bobbin equals the number of laps that it winds onto itself in a minute. The surface speed in inches per minute of the rack equals the distance up and down on the bobbin that this number of laps occupies. Hence, letting *lpi* stand for laps per inch and observing

that the surface speed of the rack is the same as the surface speed of the gear r_2 we have:

$$(16)\quad lpi = \frac{\text{excess R.P.M. } k}{\text{surface speed } r_2}.$$

Now then if we multiply the number of teeth in r_2 by the distance from the center of one tooth to the center of the next, that is, by the circular pitch, we will have the effective circumference of r_2. And this multiplied by the R.P.M. of r_2 gives us the surface speed of r_2.

We also know that the surface speed of f must always equal the excess surface speed of k in order for k to wind up the roving as delivered by f. Hence, letting S.S. stand for surface speed and cp for circular pitch, from equation (16) we have:

$$lpi = \frac{\dfrac{\text{excess S.S. } k}{\text{cir. } k}}{\text{R.P.M. } r_2 \times r_2 \times cp\ r_2}$$

$$= \frac{\text{S.S. } f_1}{\text{cir. } k \times \text{R.P.M. } r_2 \times r_2 \times cp\ r_2}$$

$$= \frac{\text{R.P.M. } f_1 \times \text{cir. } f_1}{\text{cir. } k \times \text{R.P.M. } r_2 \times r_2 \times cp\ r_2}$$

$$= \frac{\text{R.P.M. } f_1 \times 3.1416 \times \text{dia. } f_1}{3.1416 \times \text{dia. } k \times \text{R.P.M. } r_2 \times r_2 \times cp\ r_2}.$$

Canceling and rearranging we have:

$$(17)\quad \frac{lpi \times \text{dia. } k \times r_2 \times cp\ r_2}{\text{dia. } f_1} = \frac{\text{R.P.M. } f_1}{\text{R.P.M. } r_2}.$$

Now then let us find the relation of the front roll to the rack. We will consider that the center of the cone belt is at the place on the cones where it should be when the first layer is being wound on the bobbin. In this case, the top cone has a diameter of 6.25″ and the bottom cone 3.5″. From our study of gears and belts we have:

$$(18)\quad \frac{\text{R.P.M. } f_1}{\text{R.P.M. } r_2} = \frac{n_2 \times \text{dia. } n_5 \times c_2 \times c_4 \times n_9 \times v_1 \times v_5 \times v_7}{f \times \text{dia. } n_3 \times c_1 \times c_3 \times n_8 \times v \times v_4 \times v_6}.$$

Substituting the left side of (17) for the left side of (18):

$$\frac{lpi \times \text{dia. } k \times r_2 \times cp\ r_2}{\text{dia. } f_1} = \frac{n_2 \times \text{dia. } n_5 \times c_2 \times c_4 \times n_9 \times v_1 \times v_5 \times v_7}{f \times \text{dia. } n_3 \times c_1 \times c_3 \times n_8 \times v \times v_4 \times v_6}.$$

Hence:

$$(19)\quad lpi \times v_4 = \frac{n_2 \times \text{dia. } n_5 \times c_2 \times c_4 \times n_9 \times v_1 \times v_5 \times v_7 \times \text{dia. } f_1}{f \times \text{dia. } n_3 \times c_1 \times c_3 \times n_8 \times v \times v_6 \times \text{dia. } k \times r_2 \times cp\ r_2}.$$

Equation (19) gives us the *lay constant* of the frame. It is similar to the draft constant and twist constant.

PROBLEMS:

40. Using the figures in figure 1, the cone diameters for the belt position when the first layer is being wound on the empty bobbin, and taking the diameter of the empty slubber bobbin as 2″ and the circular pitch of r_2 as .392″, find from equation (19) the lay constant of the frame.

41. Work out the following formulas, letting *lc* stand for lay constant and *lg* stand for lay change gear:

$$(20)\ lc = lpi \times lg. \qquad (21)\ lg = \frac{lc}{lpi}.$$

EXAMPLE: *On the slubber in figure* 1 *find the proper lay gear to use for .49-hank roving.*

From our study of roving laps per inch in chapter IV we know that the laps per inch should = about $9.3 \times \sqrt{.49} = 6.5$ laps per inch.

Using equation (21) and the constant found in problem 40: lay gear $= \frac{238.71}{6.5} = 36.7$. Answer: About 37 teeth.

NOTE: Due to cone belt slippage, quality of staple, weather conditions, etc., the calculated gear may not give the desired results. Hence, it is necessary to "try out" the calculated gear and vary the number of teeth according to results obtained. Hence, in calculating the gear we will take the nearest whole number to the decimal.

42. What gear on the frame in figure 1 will give the proper laps per inch for .25-hank roving?

43. A certain intermediate has a lay constant of 274. What lay gear shall we use for 1.21-hank roving?

44. A certain speeder has a lay constant of 818.50. What gear shall be used for 4-hank roving?

45. A lay gear of 28 teeth on a certain jack frame is laying 52.5 laps per inch on the bobbin. What is the *actual* lay constant of the frame?

46. From formula (20) work out the following formula for changing laps per inch.

$$\text{(22)}\quad \text{required lay gear} = \frac{\text{present } lg \times \text{present } lpi}{\text{required } lpi}.$$

47. From formula (22) work out the following formula for changing hank roving when using the same twist multiplier.

$$\text{(23) required lay gear} = \frac{\text{present } lg \times \sqrt{\text{present hank roving}}}{\sqrt{\text{required hank roving}}}.$$

48. If a frame is laying the roving 10 laps to the inch with a 25-tooth lay gear, what gear will lay the roving 12 laps to the inch?

49. A 40-tooth lay gear is properly laying 4-hank roving. What gear shall we use for 5-hank roving?

50. If a 50-tooth lay gear is laying .25-hank roving properly, what gear will lay .36-hank roving properly?

51. If a 30-tooth gear on a jack frame is laying the roving 42 laps per inch, what gear will be proper to lay 52.5 laps per inch?

NOTE: Some manufacturers express the lay constants of their fly frames in terms of the twists per inch. The lay constant of the frame in figure 1 expressed in terms of twists per inch would be $\frac{1.2}{9.3}$ × the lay constant in problem 40.

TENSION GEAR

It is evident that the thicker the roving (or the less the hank roving) the greater will be the *increase* in the diameter of the bobbin as each new layer of roving is

added. Hence, in order for the roving not to stretch or break, the R.P.M. of the bobbin must decrease by bigger "jumps" for thick roving than for thin roving. This means that at the finish of the winding of each layer of thick roving the cone belt rack, y_3, must "jump" to the right farther than it must jump for thin roving. It will be observed that the larger the tension gear, the farther the rack will jump at each meshing of the bevel cone gear, n_{10}, with the bevel *gap gear*, w_4. Therefore, the teeth in the tension gear must be directly proportional to the diameter of the roving, and hence, inversely proportional to the hank roving.

In a manner similar to the manner in which we worked out the lay constant we could work out the tension constant. But so many variable conditions such as cone belt slippage, humidity, kind of cotton, twist, etc., have such a large effect upon the tension of the roving, and since the tension requires such a careful adjustment, it is hardly practical to compute the tension constant. From the equation for the tension constant, however, we could work out the following fairly practical formula similar to formulas (15) and (23) for the twist and lay gears respectively:

$$\text{(24) required tension gear} = \frac{\text{present tension gear} \times \sqrt{\text{present hank roving}}}{\sqrt{\text{required hank roving}}}.$$

EXAMPLE: *If a 20-tooth tension gear is maintaining the proper tension in .36-hank roving, about what size gear shall we use for .25-hank roving?*

Using formula (24): required tension gear $= \dfrac{20 \times \sqrt{.36}}{\sqrt{.25}} = 24.$

Answer: About a 24-tooth gear.

PROBLEMS:

52. 4-hank roving is being run with a 46-tooth tension gear. What tension gear shall we use to run 5-hank roving?

53. A 43-tension gear is maintaining the proper tension in 2.2-hank roving. What gear shall we use for 2.7-hank roving?

54. If a 34-tooth tension gear maintains the proper tension in 9-hank roving, what gear will maintain the proper tension in 12-hank roving?

Length of Time a Bobbin in the Creel will Last

Letting S.S. stand for surface speed in inches; *br* for back roll; *fr* for front roll; and letting it be understood that the quantity of roving referred to means the quantity of roving on the bobbin in the creel before any of that quantity has been unwound from the bobbin, it is evident that:

$$\begin{array}{l}\text{minutes}\\ \text{bobbin}\\ \text{in creel}\\ \text{will last}\end{array} = \frac{\text{inches of roving}}{\text{S.S. } br}$$

$$= \frac{36 \times 840 \times \text{hanks of roving}}{\dfrac{\text{S.S. } fr}{\text{draft}}}$$

$$= \frac{36 \times 840 \times \text{draft} \times \text{HR} \times \text{lbs. of roving}}{\text{S.S. } fr}$$

$$= \frac{36 \times 840 \times \text{draft} \times \text{HR} \times \dfrac{\text{ozs. of roving}}{16}}{3.1416 \times \text{dia. } fr \times \text{R.P.M. } fr}$$

$$= \frac{36 \times 840 \times \text{draft} \times \text{HR} \times \text{ozs. of roving}}{16 \times 3.1416 \times \text{dia. } fr \times \text{R.P.M. } fr}.$$

Hence:

$$(25)\quad \begin{array}{l}\text{minutes}\\ \text{bobbin}\\ \text{in creel}\\ \text{will last}\end{array} = \frac{3 \times 105 \times \text{draft} \times \text{HR} \times \text{ozs. of roving}}{.5236 \times \text{dia. } fr \times \text{R.P.M. } fr}.$$

This does not include any allowance for stoppage.

Example: *How long will a 24-oz. bobbin of 1.2-hank roving last in the creel of a speeder if the front roll of*

speeder makes 128 *R.P.M., the diameter of the front roll is* $1\frac{1}{8}$ *inches and the draft of the speeder is* 6?

Minutes that bobbin will last $= \dfrac{3 \times 105 \times 6 \times 1.2 \times 24}{.5236 \times 1\frac{1}{8} \times 128} =$ 721.9 or 12 hours 2 minutes.

55. How many hours will a 44-oz. bobbin of .50-hank roving last in the creel of an intermediate frame if the front roll makes 160 R.P.M., the diameter of the front roll is $1\frac{1}{4}$ inches and the draft is 5?

56. How many hours will a 10-oz. bobbin of 5-hank roving last in the creel of a jack frame if the front roll makes 80 R.P.M., the diameter of the front roll is $1\frac{1}{8}$ inches and the draft is 6?

Production

It is evident that the surface speed of the front roll in inches per minute is the production in inches per minute per spindle.

The term *set* refers to the filling of the bobbins. The *minutes per set* means the minutes required to fill the bobbins. We first wish to find how many minutes are required to fill the bobbins on the frame.

$$\begin{aligned}\text{minutes per set} &= \frac{\text{yds. on full bobbin}}{\text{yds. produced in 1 minute}} = \frac{\text{yds. on full bobbin}}{\frac{\text{S.S. } fr}{36}} \\ &= \frac{36 \times \text{yds. on full bobbin}}{\text{S.S. } fr} \\ &= \frac{36 \times 840 \times \text{hanks on full bobbin}}{\text{S.S. } fr} \\ &= \frac{36 \times 840 \times \text{HR} \times \text{lbs. on full bobbin}}{\text{S.S. } fr} \\ &= \frac{36 \times 840 \times \text{HR} \times \frac{\text{ozs. on full bobbin}}{16}}{\text{S.S. } fr}\end{aligned}$$

Hence:

$$(26)\quad \text{minutes per set} = \frac{3 \times 105 \times \text{HR} \times \text{ozs. on full bobbin}}{.5236 \times \text{R.P.M. } fr \times \text{dia. } fr}.$$

To find the sets per day we must add to the minutes per set the minutes required to doff the frame. Hence:

$$\text{(27) sets per 10 hrs.} = \frac{600}{\text{min. per set} + \text{min. for doffing each set}}.$$

It is also evident that:

$$\text{(28)}\ \begin{array}{l}\text{production (in lbs.) per}\\ \text{spindle per 10 hrs.}\end{array} = \text{sets per 10 hrs.} \times \text{lbs. per set.}$$

$$\text{(29)}\ \begin{array}{l}\text{production (in hanks)}\\ \text{per spindle per 10 hrs.}\end{array} = \begin{array}{c}\text{production (in lbs.) per}\\ \text{spindle per 10 hours}\end{array} \times \text{HR}.$$

But roving contracts due to twisting after leaving the front roll. Hence, from the speed of the front roll in equation (26) we must deduct the percentage that the yarn contracts in twisting.

EXAMPLE: *If a full slubber bobbin contains* 44 *oz. of roving and the R.P.M. of the* $1\frac{1}{4}$*-inch front roll is* 138 *when producing* 1*-hank roving, what will be the production of* 1*-hank roving per spindle for* 10 *hours, allowing* 15 *minutes for doffing each set and* 3% *contraction due to twisting?*

$$138 \text{ less } 3\% = 133.8 \text{ (or 134).}$$

From equation (26):

$$\text{minutes per set} = \frac{3 \times 105 \times 1 \times 44}{.5236 \times 134 \times \frac{5}{4}} = 158.0.$$

From equation (27):

$$\text{sets per 10 hrs.} = \frac{600}{158 + 15} = 3.46.$$

From equation (28):

$$\text{production in lbs. per spindle per 10 hrs.} = 3.46 \times \tfrac{44}{16} = 9.52.$$

From equation (29):

$$\text{production in hanks per spindle per 10 hrs.} = 9.52 \times 1 = 9.52.$$

PROBLEMS: *Calculate the production in the following problems, allowing* 15 *minutes for doffing each set and* 3% *for contraction. Fill in the blank spaces in the last three columns.*

Problem Number	Fly Frame	Size of Full Bobbin	Weight (in ozs.) of Full Bobbin	R.P.M. of Front Roll	Diameter of Front Roll	Hank Roving	Production per Spindle per 10 Hours		
							Sets	Lbs.	Hanks
57.	Slubber	12″ by 6″	44	306	$1\frac{1}{4}$″	.20			
58.	Slubber	11″ by $5\frac{1}{2}$″	32	140	$1\frac{1}{4}$″	1.20			
59.	Intermediate	9″ by $4\frac{1}{2}$″	18	146	$1\frac{1}{4}$″	2.00			
60.	Speeder	7″ by $3\frac{1}{2}$″	10	125	$1\frac{1}{8}$″	5.00			
61.	Jack	6″ by 3″	7	100	$1\frac{1}{8}$″	10.00			

CHAPTER X

RING SPINNING FRAME CALCULATIONS

The upper part of figure 1 represents an end view of a ring spinning frame and the lower part represents a top view of the drawing rolls.

w_8 in the upper part is an end view of the shaft of the front drawing rolls. A top view of this same shaft is shown in the lower part of the figure and is marked again w_8. w_8 is pronounced like this: "*w* sub 8."

Ratio of Spindle Speed to Cylinder Speed

Since the cylinder, *n*, the whirl, *s*, and the band, *n*, are the same as pulleys and belts:

$$(1)\quad \frac{\text{R.P.M. of } s}{\text{R.P.M. of } n} = \frac{\text{dia. of } n}{\text{dia. of } s}.$$

Note: Hereafter we shall omit the word "of" after R.P.M., dia., etc.

Allowances for Band Drive. The effective diameter of a pulley (see chapter XX, part I) is the actual diameter of the pulley plus the thickness of the belt. Obtaining the correct effective diameter is important in the case of very small pulleys. Hence, we must add to the above diameters the thickness of the band which is usually $\frac{1}{8}''$.

Another allowance must be made because the whirl is measured at the bottom of the groove and the band does not fit down into the bottom of the groove, but keeps about $\frac{1}{16}''$ away from the bottom. Hence, with a band drive the formula for the ratio of spindle speed to cylinder speed becomes:

$$(2)\quad \frac{\text{R.P.M. } s}{\text{R.P.M. } n} = \frac{\text{dia. } n + \frac{1}{8}''}{\text{dia. } s + \frac{3}{16}''}, \text{ (for band drive).}$$

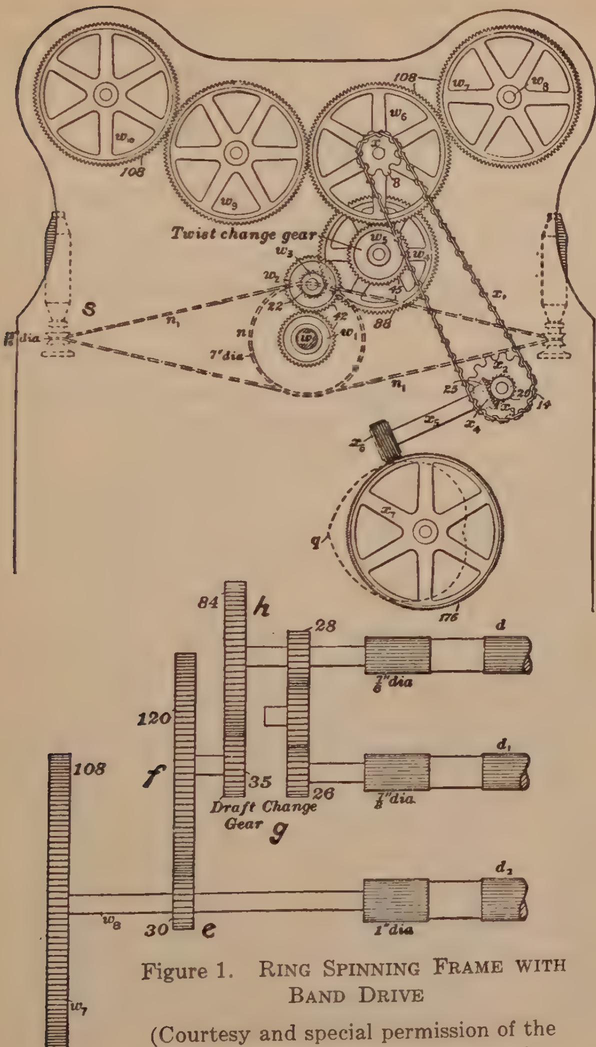


Figure 1. RING SPINNING FRAME WITH BAND DRIVE

(Courtesy and special permission of the International Textbook Company)

Allowance for Tape Drive. The tape of a tape drive is usually about $\frac{1}{16}''$ thick and fits tightly against the crown of the whirl. Hence, the formula becomes:

$$(3)\quad \frac{\text{R.P.M. } s}{\text{R.P.M. } n} = \frac{\text{dia. } n + \frac{1}{16}''}{\text{dia. } s + \frac{1}{16}''} \text{ (for tape drive).}$$

EXAMPLE: *What is the ratio of spindle speed to cylinder speed of a band drive with $\frac{3}{4}''$ whirl and $6''$ cylinder?*

$$\text{Ratio of spindle speed to cylinder speed} = \frac{6 + \frac{1}{8}}{\frac{3}{4} + \frac{3}{16}} = 6.53.$$

PROBLEM:

1. Fill in the spaces in the following table for future use. The ratio from the above example is put in its proper place.

RATIOS OF SPINDLE SPEEDS TO CYLINDER SPEEDS

Diameter of Cylinder	Kind of Drive	Diameter of Whirl					
		$\frac{3}{4}$ inch	$\frac{13}{16}$ inch	$\frac{7}{8}$ inch	1 inch	$1\frac{1}{8}$ inch	$1\frac{1}{4}$ inch
6 inches	Band	6.53					
	Tape						
7 inches	Band						
	Tape						
8 inches	Band						
	Tape						
9 inches	Band						
	Tape						
10 inches	Band						
	Tape						

SUGGESTION TO TEACHERS: Assign each column to different groups in the class.

Tables and Measurements. Manufacturers of spinning frames publish ratios for use with their own machinery. Some of them, for the groove allowance, add .3 of the thickness of the band instead of $\frac{1}{16}''$. Some make the *actual* diameters enough larger than the *nominal* diameters that no groove allowance is necessary when calculating with the *nominal* diameter. One manufacturer so makes the actual diameters of the tape and band whirls that the ratios of the nominal whirl diameters to the cylinder diameters are the same for both tape and band drives. Therefore, in accurately calculating this ratio you must know the *actual* diameter of the whirl and make the proper allowances. In finding this ratio from manufacturers' tables you must know the *nominal* diameter.

Slippage. It is evident that if the band or tape slips the *actual* ratio of spindle speed to cylinder speed is *less* than the *calculated* ratio. An allowance for slippage is sometimes made, as will be explained later.

Obtaining the Actual Ratio. On the foot end of the frame make a fine chalk mark coinciding exactly with a fine chalk mark on the cylinder. On the latch make a similar chalk mark coinciding with a chalk mark on the whirl. Then while you turn the pulley and count the number of turns of the cylinder have another person count the turns of the whirl. Keep turning and counting until the marks again exactly coincide. Divide the turns of the spindle by the turns of the cylinder. It is evident that finding the ratio in this manner eliminates all necessity of measuring and making allowances for groove, band or tape thickness and slippage. The actual ratio may also be found by the use of the speed indicator.

EXAMPLE: *What is the speed ratio if it requires* 5 *turns of the cylinder and* 26 *of the whirl to make the marks again coincide?*

$$\text{Ratio} = \frac{26}{5} = 5.2.$$

PROBLEMS. *Find the actual ratio in the following cases:*

2. To make the marks again exactly coincide requires 10 turns of the cylinder and 71 of the whirl.

3. To make the marks again exactly coincide requires 5 turns of the cylinder and 41 of the whirl.

4. To make the marks again exactly coincide requires 25 turns of the cylinder and 204 of the whirl

5. To make the marks again exactly coincide requires 20 turns of the cylinder and 123 of the whirl.

TWISTS PER INCH

EXAMPLE: *Suppose that the surface speed of the front roll,* d_2, *in figure* 1 *is* 600 *inches per minute; that the whirl,* s, *makes* 8000 *R.P.M. and that the bobbin is* 3″ *in circumference. How many twists per inch are inserted in the yarn?*

Since the surface speed of the front roll, d_2, is 600 inches per minute, d_2 delivers 600 inches per minute and the bobbin winds onto itself 600 inches per minute. Since the bobbin is 3″ in circumference, 200 R.P.M. of the bobbin are required to wind up the yarn ($\frac{600}{3} = 200$). But the whirl s, and consequently the bobbin, makes 8000 R.P.M. Hence, 7800 R.P.M. of the bobbin are used in twisting the yarn ($8000 - 200 = 7800$). Since 600 inches of yarn receive 7800 twists, each inch receives 13 twists ($\frac{7800}{600} = 13$). Incidentally, it is evident from the above that the speed of the traveler is 7800 R.P.M.

Inaccuracies in Twist Calculations. However, in calculating twists per inch we do not bother to deduct from the R.P.M. of the bobbin the R.P.M. required to wind up the yarn. We would calculate the twist per inch like this: $\frac{8000}{600} = 13.33$. It is evident that this *calculated* twist per inch is .33 of a turn *greater* than the *actual* twist per inch.

Another inaccuracy in twist calculations is due to the constant changing of the circumference of the bobbin. It is evident from the above example that the larger the circumference of the bobbin the fewer the R.P.M. required to wind up the yarn, and hence the more the R.P.M. of the bobbin devoted to twisting. Hence, the yarn wound on the outside of the bobbin has slightly *more* twists per inch than the yarn on the inside.

Another inaccuracy in twist calculations is due to the fact that yarn contracts in twisting, thereby tending to make the *calculated* twists per inch *less* than the *actual* twists.

Another inaccuracy in twist calculations is due to the slippage of the bands or tapes. It is evident that slippage of the band causes the spindle to make fewer R.P.M. and consequently fewer twists per inch, thereby tending to make the *calculated* twists per inch *greater* than the *actual* twists.

It is evident from the above that some of these inaccuracies tend to correct each other. For instance: in the above example winding up the yarn on the bobbin caused the calculated twists to be $2\frac{1}{2}\%$ *greater* than the actual twists. Contracting in twisting may cause the calculated twists to be 3% *greater* than actual twists. Slippage often amounts to 5%, making the calculated twists 5% *less* than actual twists. Hence, for all practical purposes:

$$\text{twists per inch} = \frac{\text{R.P.M. of the spindle}}{\text{surface speed of the front roll}}.$$

Letting *tpi* stand for twists per inch, S.S. for surface speed and referring to figure 1 the above equation becomes:

$$(4)\quad tpi = \frac{\text{R.P.M. } s}{\text{S.S. } d_2}.$$

PROBLEMS. *Find the twists per inch in the following cases:*

6. Surface speed of front roll 567 inches per minute. Speed of spindle 4000 R.P.M.

7. Front roll makes 200 R.P.M. and is $1\frac{1}{8}''$ in diameter. Speed of bobbin 6200 R.P.M.

8. Front roll makes 100 R.P.M. and is $\frac{7}{8}''$ in diameter. Speed of bobbin 9650 R.P.M.

9. Is the speed of the traveler constant? Prove your answer by an example.

Twists per Inch and Twist Change Gears

Referring to figure 1 and from what we have learned about R.P.M. and surface speed we know that: R.P.M. of d_2 × circum. of d_2 = S.S. of d_2. Hence:

(5) $\text{R.P.M. } d_2 = \dfrac{\text{S.S. } d_2}{\text{cir. } d_2}$. From what we have learned of pulley speeds and gear trains we know that:

(6) $\dfrac{\text{R.P.M. } s}{\text{R.P.M. } d_2} = \dfrac{\text{dia. } n \times w_2 \times w_4 \times w_7}{\text{dia. } s \times w_1 \times w_3 \times w_5}$. Substituting from (5) into (6):

$$\frac{\text{R.P.M. } s}{\dfrac{\text{S.S. } d_2}{\text{cir. } d_2}} = \frac{\text{dia. } n \times w_2 \times w_4 \times w_7}{\text{dia. } s \times w_1 \times w_3 \times w_5}.$$ Simplifying the left side:

$$\frac{\text{R.P.M. } s \times \text{cir. } d_2}{\text{S.S. } d_2} = \frac{\text{dia. } n \times w_2 \times w_4 \times w_7}{\text{dia. } s \times w_1 \times w_3 \times w_5}.$$

Dividing both sides by cir. d_2:

$$\frac{\text{R.P.M. } s}{\text{S.S. } d_2} = \frac{\text{dia. } n \times w_2 \times w_4 \times w_7}{\text{dia. } s \times w_1 \times w_3 \times w_5 \times \text{cir. } d_2}.$$

Substituting from equation (4) into the left side and dividing both numerator and denominator of the right side by dia. of s:

$$tpi = \frac{\dfrac{\text{dia. } n}{\text{dia. } s} \times w_2 \times w_4 \times w_7}{w_1 \times w_3 \times w_5 \times \text{cir. } d_2}.$$

Substituting from equation (1):

(7) $tpi = \dfrac{w_2 \times w_4 \times w_7 \times \dfrac{\text{R.P.M. } s}{\text{R.P.M. } n}}{w_1 \times w_3 \times w_5 \times \text{cir. } d_2}$. Hence, the formula for the twist change gear is:

(8) $w_5 = \dfrac{w_2 \times w_4 \times w_7 \times \dfrac{\text{R.P.M. } s}{\text{R.P.M. } n}}{w_1 \times w_3 \times tpi \times \text{cir. } d_2}$.

EXAMPLE: *Find the twist change gear required on the frame in figure* 1 *to insert* 14 *twists per inch. Use the calculated ratio of speeds from problem* 1.

$$w_5 = \frac{42 \times 88 \times 108 \times 7.125}{42 \times 22 \times 14 \times 3.1416} = 69.9.$$

Answer: 69-tooth gear.

PROBLEMS AND QUESTIONS:

10. (*a*) Are the twist change gear and the twists per inch directly or inversely proportional?

(*b*) Will a 69-tooth gear in the above example insert slightly more or less than 14 twists per inch?

(*c*) Will slippage of the band insert slightly more or less than 14 twists per inch?

(*d*) Does or does not slippage tend to overcome the dropping of the decimal?

11. Find the twist change gear required on the band-driven frame in figure 1 to insert 17.5 twists per inch. Refer to problem 1 for the ratio.

12. Find the twist change gear required in the band-driven frame in figure 1 to insert 21 twists per inch.

13. In the band-driven frame in figure 1 find the twist change gear required to insert 19 twists per inch if:

Diameter of cylinder = 8″.	w_2 has 48 teeth.
Diameter of whirl = $\frac{3}{4}$″.	w_3 has 24 teeth.
Diameter of front roll = $1\frac{1}{8}$″.	w_4 has 96 teeth.
w_1 has 44 teeth.	w_7 has 110 teeth.

14. If the frame in figure 1 remains the same as in problem 13, what size twist change gear will be required to insert 23.75 twists per inch?

Twist Constants

The use of *twist constants* greatly shortens the labor in figuring twist change gears and twists per inch. From equation (8) and using the figures in figure 1 and the proper speed ratio from problem 1 we have:

$$(9)\quad w_5 \times tpi = \frac{w_2 \times w_4 \times w_7 \times \dfrac{\text{R.P.M. } s}{\text{R.P.M. } n}}{w_1 \times w_3 \times \text{cir. } d_2}$$

$$= \frac{42 \times 88 \times 108 \times 7.125}{42 \times 22 \times 3.1416} = 979.75.$$

Hence, as long as the ratio of spindle to cylinder speed, the front roll and the rest of the gears are unchanged, the product of the twist change gear multiplied by the twists per inch remains constant, regardless of the size of the change gear and the number of twists per inch. This product is called the *twist constant.* Hence, the twist constant of the frame shown in figure 1 is 979.75.

Letting tc stand for twist constant and tg for twist change gear we have the following formulas:

$$(10)\quad tc = tpi \times tg. \qquad (11)\quad tg = \frac{tc}{tpi}. \qquad (12)\quad tpi = \frac{tc}{tg}.$$

Example: *Find the twist change gear required on the band-driven frame in figure* 1 *to insert* 14 *twists per inch.*

Using formula (11) we have $tg = \dfrac{tc}{tpi} = \dfrac{979.75}{14} = 69.9.$

Answer: 69-tooth gear

Finding the Twist Change Gear

15. Find the twist change gear required on the band-driven frame in figure 1 to insert $17\frac{1}{2}$ twists per inch.

16. Find the twist change gear required on the frame in problem 15 to insert 21 twists per inch.

17. The twist constant of a certain frame is 1020. What twist change gear will insert 20 twists per inch?

18. The twist constant of a certain frame is 990. What twist change gear will insert 15 twists per inch?

19. The twist constant of a certain frame is 504. What twist change gear will insert 24 twists per inch?

Finding the Twists per Inch

EXAMPLE: *The twist constant is* 506. *What twists per inch will a* 46-*tooth change gear insert?*

Using formula (12): $tpi = \frac{tc}{tg} = \frac{506}{46} = 11.$

20. The twist constant is 750. What twists per inch will a 47-tooth change gear insert?

21. The twist constant is 829. What twists per inch will a 41-tooth change gear insert?

22. The twist constant is 957. What twists per inch will a 31-tooth change gear insert?

Since the *mechanical,* or *calculated,* twists per inch differ from the *actual* twists per inch, if we know the *actual* twists per inch and the twist gear, by the use of formula (10) we can *approximate* the twist constant, but cannot find it exactly. This approximate twist constant is called the *actual* twist constant.

EXAMPLE: *A certain frame is inserting* 17.45 *twists per inch with a* 55-*tooth change gear. What is the actual twist constant?*

Using formula (10), $tc = tpi \times tg = 17.45 \times 56 = 977.20$ (approximate).

23. A certain frame is inserting 21.45 twists per inch with a 46-tooth change gear. What is the approximate twist constant?

24. A certain frame is inserting 41.04 twists per inch with a 26-tooth change gear. What is the approximate twist constant?

25. A certain frame is inserting 16.5 twists per inch with a 56-tooth change gear. What is the approximate twist constant?

26. If we should later use the approximate twist constants found in problems 23, 24 and 25, in finding twist gears should we make allowances for slippage even if the slippage be large?

27. Are the actual twist constants found in problems 23 to 25 larger or smaller than the twist constants?

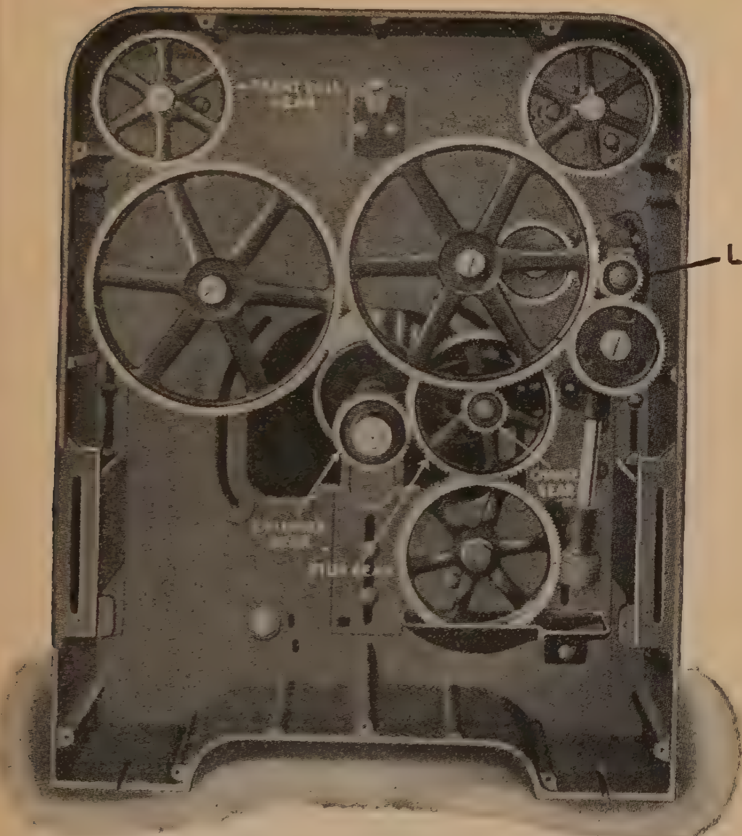
The only way we can find the twist constant exactly is by calculating from the front roll, speed ratio and gears as we did in equation (9).

28. Find the twist constant of the band-driven frame in figure 1 if:

The diameter of the front roll is as shown in the figure.

The diameter of the cylinder equals 8 inches.
The diameter of the whirl equals $\frac{7}{8}$ of an inch.
Gear w_1 has 36 teeth.
Gear w_2 has 48 teeth.
Gear w_3 has 22 teeth.
Gear w_4 has 66 teeth.
Gear w_7 is as shown in the figure.

29. Work out a formula for the twist constant of the frame in figure 2 similar to equation (9), letting *fr* stand for front roll, *cy* for cylinder and *w* for whirl, and the letters in figure 2 for the teeth of the gears.



c = cylinder gear. *s* = stud gear.
tg = twist change gear. *f* = front roll driven gear.
cy = cylinder. *w* = whirl. *fr* = front roll.

Figure 2. Tape Drive Spinning Frame Twist Gearing

The manufacturer of the frame in figure 2 builds it with an almost limitless variety of combinations of gearing, cylinders, whirls and rolls. In the following

table are given a few of the stock combinations. The speed ratios in the table have been found by *actual* test in the manufacturer's factory.

FINDING THE TWIST CONSTANT

Write into the empty column in the following table the twist constant of each combination, using the formula worked out in problem 28.

Problem Number	Diameter of Cylinder	Diameter of Whirl	Ratio of Spindle to Cylinder Speeds	Teeth in Cylinder Gear	Teeth in Stud Gear	Teeth in Front Roll Driven Gear	Diameter of Front Roll	Twist Constant
30.	7″	$\frac{7}{8}$″	7.80	26	132	100	1″	
31.	7″	$\frac{15}{16}$″	7.27	26	112	100	1″	
32.	7″	$1\frac{1}{8}$″	6.09	46	92	100	$1\frac{1}{8}$″	
33.	7″	$1\frac{5}{16}$″	5.22	69	69	100	$1\frac{1}{8}$″	
34.	8″	$\frac{7}{8}$″	8.80	26	132	100	1″	
35.	8″	1″	7.80	26	92	100	1″	
36.	8″	$1\frac{1}{16}$″	7.30	46	92	100	$1\frac{1}{8}$″	
37.	8″	$1\frac{5}{16}$″	5.90	69	69	100	$1\frac{1}{8}$″	

38. Make a diagram of the twist gearing of one of the frames in your mill, measuring the diameters of the cylinder and whirl with a pair of calipers. Calculate the ratio of spindle to cylinder speeds. Check this calculation by actual test either with a speed indicator or by making chalk marks and turning by hand. Calculate the twist constant. By use of the twist constant compute the twists per inch that the frame is inserting in the yarn.

Take some of the yarn off the frame, put it into the twist counter and find the twists per inch. Check this actual twist with the calculated twists per inch.

Percent of Slippage

EXAMPLE: *A spindle of a certain frame having a twist constant of* 792.00 *is inserting* 33.00 *twists per inch with a* 23-*tooth twist gear. What is the percent of slippage?*

$tpi = \frac{tc}{tg} = \frac{792}{23} = 34.43$. $34.43 - 33.00 = 1.43$ = loss of twists per inch. $\frac{1.43}{34.43} = .041$. $\therefore$ slippage = 4.1%.

PROBLEMS. *Find the percent of slippage in the following problems:*

39. A frame having a constant of 782 is inserting 23 twists per inch with a 32-tooth twist gear.

40. A frame with a constant 996.84 is inserting standard twist in 36s warp with a 34-tooth gear.

41. 20s standard twist warp is having the proper amount of twist inserted with a 34-tooth gear on a frame with a constant of 764.

42. A frame with a constant of 757.52 is inserting the proper amount of standard twist in 22s warp with a 34-tooth change gear.

43. What was the percent of slippage in problem 38?

44. If we find the twist constant of a frame from the actual amount of twist being inserted and by counting the teeth in the twist change gear, and then right away use this twist constant, need we make any allowance for slippage even if the slippage be large? Why?

45. The ratios in problems 30 to 37 have been found by actual test in the manufacturer's plant. In using the constants found in problems 30 to 37 in the mill, should we take it for granted that no allowance need be made for slippage?

Combinations of Formulas

Following are some combinations of twist formulas that are in common use:

To find the required twist gear when the present twist gear, present twists per inch and required twists per inch are known:

The above condition assumes, of course, that the twist constant remains unchanged, hence from equation (10):

tc = present *tpi* × present *tg*. *tc* = required *tpi* × required *tg*. Since the left sides are equal, the right sides must be equal.

∴ required *tpi* × required *tg* = present *tpi* × present *tg*. Hence:

$$(13)\quad \text{required } tg = \frac{\text{present } tpi \times \text{present } tg}{\text{required } tpi}.$$

Example: *A frame is inserting* 19 *twists per inch with a* 32-*tooth twist gear. What twist gear will insert* 23.75 *twists per inch?*

Using formula (13): required $tg = \frac{19 \times 32}{23.75} = 25.6$.

Answer: 25 or 26-tooth gear.

Problems and Questions:

46. In the preceding example need there be any consideration of slippage?

47. If 17.50 *tpi* are being inserted with a 42-tooth gear, what gear will insert 21 *tpi*?

48. If 19.80 *tpi* are being inserted with a 39-tooth gear, what gear will insert 17.85 *tpi*?

49. If 22.41 *tpi* are being inserted with a 43-tooth gear, what gear will insert 21 *tpi*?

50. If 19.17 *tpi* are being inserted with a 40-tooth gear, what gear will insert 22.14 *tpi*?

51. If 26.02 *tpi* are being inserted with a 30-tooth gear, what gear will insert 21.24 *tpi*?

To find the twist gear when the counts and twist constant are known:

From the relation of counts to twist and letting *tm* stand for twist multiplier, we know that $tpi = tm \times \sqrt{\text{counts}}$. From equation (12) $tpi = \frac{tc}{tg}$. Since the left sides are equal, the right sides are equal. Hence, $tm \times \sqrt{\text{counts}} = \frac{tc}{tg}$. Therefore:

$$(14)\quad tg = \frac{tc}{tm \times \sqrt{\text{counts}}}.$$

EXAMPLE: *What twist gear should be used for* 30s *filling extra twist if the twist constant is* 981.05?

$$\text{twist gear} = \frac{981.05}{3.5 \times \sqrt{30}} = \frac{981.05}{3.5 \times 5.477} = 51.$$

PROBLEMS:

52. A frame has a constant of 926. What size twist gear should be used for 40s filling?

53. A frame has a constant of 887.12. What size twist gear shall we use for 30s warp?

54. What twist gear must be used for 26s filling if the constant of the frame is 910.02?

55. If the frame constant is 849.75, what twist gear shall we use for 20s warp?

To find the required twist gear when the present counts and the required counts are known:

The above condition assumes, of course, that the twist constant and twist multiplier remain the same. From equation (13), and from the relation of counts to twists per inch and letting *tm* stand for twist multiplier:

$$\text{required } tg = \frac{\text{present } tpi \times \text{present } tg}{\text{required } tpi}$$

$$= \frac{tm \times \sqrt{\text{present counts}} \times \text{present } tg}{tm \times \sqrt{\text{required counts}}}. \quad \text{Canceling:}$$

$$(15)\quad \textbf{required } tg = \frac{\sqrt{\textbf{present counts}} \times \textbf{present } tg}{\sqrt{\textbf{required counts}}}.$$

EXAMPLE: *A 54-tooth twist gear is inserting the proper twist in 18s yarn. What gear will insert the proper twist in 24s yarn?*

$$\text{required } tg = \frac{\sqrt{18} \times 54}{\sqrt{24}} = \frac{\sqrt{3} \times \sqrt{6} \times 54}{2 \times \sqrt{6}} = \sqrt{3} \times 27$$
$$= 1.73 \times 27 = 46.7.$$

PROBLEMS:

56. A frame is using a 30-tooth gear for 25s. What gear must be used for 36s?

57. A 28-tooth twist gear is used for 30s. What gear must be used for 28s?

58. 35s is twisted with a 26-tooth gear. Find the proper gear for 21s.

59. 16s is being twisted with a 62-tooth gear. What gear shall be used for 12s?

Draft and Draft Change Gears

In the diagram of the drawing rolls in figure 1 we know from our study of gear trains that:

$\frac{\text{R.P.M. } d_2}{\text{R.P.M. } d} = \frac{f \times h}{e \times g}$. We also know from our study of surface speed that R.P.M. $= \frac{\text{S.S.}}{3.1416 \times \text{dia.}}$. Hence:

$$\frac{\dfrac{\text{S.S. } d_2}{3.1416 \times \text{dia. } d_2}}{\dfrac{\text{S.S. } d}{3.1416 \times \text{dia. } d}} = \frac{f \times h}{e \times g}.$$ Simplifying the left side:

$$\frac{\text{S.S. } d_2 \times 3.1416 \times \text{dia. } d}{\text{S.S. } d \times 3.1416 \times \text{dia. } d_2} = \frac{f \times h}{e \times g}.$$ Therefore:

$$\frac{\text{S.S. } d_2}{\text{S.S. } d} = \frac{f \times h \times \text{dia. } d_2}{e \times g \times \text{dia. } d}.$$ Hence from our study of draft:

$$\text{(16) draft} = \frac{f \times h \times \text{dia. } d_2}{e \times g \times \text{dia. } d}.$$ Therefore:

$$\text{(17) } g = \frac{f \times h \times \text{dia. } d_2}{e \times \text{draft} \times \text{dia. } d}.$$

EXAMPLE: *If* g, *the draft gear* (*short for "draft change gear"*), *has* 35 *teeth, what is the draft of the frame as shown in figure* 1?

Using equation (16) we have: draft $= \frac{120 \times 84 \times 1}{30 \times 35 \times \frac{7}{8}} = 10.97.$

PROBLEMS:

60. What is the draft in figure 1 if g has 36 teeth?

61. What is the draft in figure 1 if g has 30 teeth?

62. What is the draft in figure 1 if g has 32 teeth?

63. What is the draft in figure 1 if g has 40 teeth?

EXAMPLE: *What draft gear in figure* 1 *will insert a draft of* 9?

Using equation (17) we have:

$$\text{draft gear} = \frac{120 \times 84 \times 1}{30 \times 9 \times \frac{7}{8}} = 42.6. \quad \text{Answer: 42 or 43.}$$

PROBLEMS AND QUESTIONS:

64. (*a*) Are the draft gear and the draft directly or inversely proportional? Why?

(*b*) In the preceding example which of the two gears (42 and 43) will insert more draft and which less draft than the desired draft of 9?

(*c*) Which gear would be used if it were found that the roving delivered by the card room was slightly lighter than that ordered?

65. In figure 1 what size draft gear would be required to insert a draft of 7?

66. In figure 1 what size draft gear would be required to insert a draft of 9.2 if: *e* has 31 teeth, *f* 124 and *h* 91 teeth?

67. In problem 66 what size draft gear will be required to insert a draft of 13?

DRAFT CONSTANTS

The use of *draft constants* shortens the labor in calculating draft and draft gears. From equation (17) and using the figures in figure 1 we have:

$$(18) \quad g \times \text{draft} = \frac{f \times h \times \text{dia.}\, d_2}{e \times \text{dia.}\, d} = \frac{120 \times 84 \times 1}{30 \times \frac{7}{8}} = 384.$$

Hence, as long as the rolls and other gears remain the same, the *product* of the draft gear multiplied by the draft remains constant regardless of the amount of draft and the size of the draft gear. This product is called the *draft constant*. Hence, the draft constant of the frame as shown in figure 1 is 384. Letting *dc* stand for draft constant and *dg* stand for draft gear we have the following formulas:

$$(19) \quad dc = dg \times \text{draft}. \qquad (20) \quad dg = \frac{dc}{\text{draft}}. \qquad (21) \quad \text{draft} = \frac{dc}{dg}.$$

EXAMPLE: *Find the draft gear required to insert a draft of* 8.66 *on the frame in figure* 1.

Draft constant found in equation (18) is 384.

Using formula (20): $dg = \dfrac{384}{8.66} = 44.3.$ Answer: 44 teeth.

FINDING THE DRAFT GEAR

68. Find the draft gear required in figure 1 to insert a draft of 9.5.

69. Find the draft gear required in figure 1 to insert a draft of 10.11.

70. The draft constant of a certain frame is 411.60. What size gear will insert 8.23 draft?

71. The draft constant of a certain frame is 463.05. What size gear will insert 11.29 draft?

72. The draft constant of a certain frame is 235.20. What size gear will insert 9.41 draft?

FINDING THE DRAFT

EXAMPLE: *What draft will a* 46-*tooth gear on the frame in figure* 1 *insert?*

Using formula (21): $\text{draft} = \dfrac{384}{46} = 8.39.$

73. The draft constant of a certain frame is 268.80. What draft will a 29-tooth draft gear insert?

74. The draft constant of a certain frame is 512.00. What draft will a 50-tooth draft gear insert?

75. The draft constant of a certain frame is 441.60. What draft will a 34-tooth draft gear insert?

Finding the Actual Draft Constant; Contraction Due to Twisting

If actual draft were based upon the weight and length of yarn just as it comes out of the front rolls, before any twist is inserted, actual draft and mechanical draft would be practically the same. But yarn contracts due to twisting.

EXAMPLE. *20s yarn is being spun from single 3-hank roving. The rolls have a mechanical draft of 6.87. Find the percent of contraction due to twisting.*

From our study of actual draft we know that:

$$\text{actual draft} = \frac{\text{counts delivered} \times \text{doublings}}{\text{hank roving fed}} = \frac{20 \times 1}{3} = 6.66.$$

$6.66 \div 6.87 = .97$. $1.00 - .97 = .03$. Therefore, contraction *in this case* is 3%.

Hence, if we know the draft gear and the actual draft, by the use of formula (19), we can *approximate* the draft constant of the frame, but cannot find it exactly.

EXAMPLE: *A frame is inserting actual draft of 6.72 with a 41-tooth draft gear. What is the approximate, or actual, draft constant?*

Using formula (19): $dc = 41 \times 6.72 = 275.52$ (approximate).

76. What is the approximate draft constant if a 35-tooth gear is inserting a draft of 9.14?

77. What is the approximate draft constant if a 27-tooth gear is inserting a draft of 9.80?

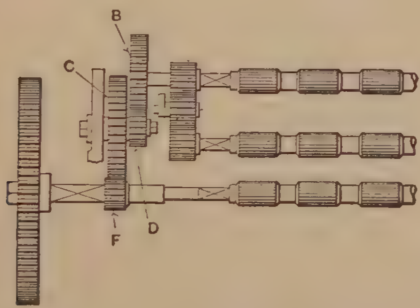
78. What is the approximate draft constant if a 34-tooth gear is inserting a draft of 12.79?

79. Are the approximate draft constants found in problems 76 to 78 larger or smaller than the draft constants? Why?

80. If the draft constant of the frame in problem 76 is 339.21, what is the percent of contraction due to twisting?

The only way we can find the draft constant exactly is by calculating from the rolls and gears as we did in equation (18).

81. Find the draft constant from the frame in figure 1, if e has 31 teeth, f 124 teeth and h 91 teeth.



B = back roll gear.
F = front roll driver gear.
br = back roll.
C = crown gear.
D = draft gear.
fr = front roll.

Figure 3. DRAWING ROLLS OF THE SPINNING FRAME SHOWN IN FIGURE 2

82. Work out a formula for the draft constant of the frame shown in figure 3 similar to equation (18), using the letters shown in figure 3.

The manufacturer of the frame shown in figure 3 builds it with the combinations of gears and rolls shown in the following table.

Write into the empty column in the following table the draft constant of each combination, using the formula worked out in problem 82.

PROBLEM NUMBER	DIAMETER OF FRONT ROLL	FRONT ROLL DRIVER GEAR TEETH	CROWN GEAR TEETH	BACK ROLL GEAR TEETH	DIAMETER OF BACK ROLL	DRAFT CONSTANT
83.	1″	28	84	84	⅞″	
84.	1″	30	60	84	⅞″	
85.	1″	30	84	84	⅞″	
86.	1″	30	120	84	⅞″	
87.	1″	30	168	84	⅞″	
88.	1⅛″	30	120	84	1⅛″	
89.	1⅛″	32	114	80	1⅛″	

90. Make a diagram of the draft gearing of one of the frames in your mill. Calculate the draft constant. By use of the draft constant and the draft gear in use, calculate the amount of draft being inserted. Then find out the hank roving and counts being run. Determine the *actual* draft and find the percent of contraction.

COMBINATIONS OF ACTUAL DRAFT AND MECHANICAL DRAFT FORMULAS

To find the required draft gear when the present draft, present draft gear and the desired draft are known:

Let ($_1$) after a word mean "present" and ($_2$) after a word mean "required." From formula (19): $dc = dg_1 \times \text{draft}_1$ and $dc = dg_2 \times \text{draft}_2$. Hence, $dg_1 \times \text{draft}_1 = dg_2 \times \text{draft}_2$. Therefore:

$$(22)\ dg_2 = \frac{dg_1 \times \text{draft}_1}{\text{draft}_2}.$$

EXAMPLE: *A frame has a draft of 7 with a 50-tooth draft gear. What gear is required for a draft of 9?*

$$\text{required draft gear} = \frac{50 \times 7}{9} = 37.7.\quad \text{Answer: 37 or 38 teeth.}$$

To find the required draft gear when the present counts, present draft gear, present hank roving and the required counts and hank roving to be fed are known:

From formula (22) and our study of actual draft:

$$dg_2 = \frac{dg_1 \times \text{draft}_1}{\text{draft}_2} = \frac{dg_1 \times \dfrac{\text{counts}_1 \times \text{doublings}}{\text{hank roving}_1}}{\dfrac{\text{counts}_2 \times \text{doublings}}{\text{hank roving}_2}}.$$

Simplifying and canceling:

$$(23)\ dg_2 = \frac{dg_1 \times \text{counts}_1 \times \text{hank roving}_2}{\text{counts}_2 \times \text{hank roving}_1}.$$

EXAMPLE: *24s yarn is being spun from 3-hank roving, using a 32-tooth draft gear. What gear must be used to spin 20s from 2.75-hank roving?*

Using formula (23):

$$\text{required draft gear} = \frac{32 \times 24 \times 2.75}{20 \times 3} = 35.2.\quad \text{Answer: 35 teeth.}$$

To find the required draft gear when the present counts, present draft gear and required counts are known, the hank roving remaining the same:

In formula (23) we see that if hank roving remains the same it will cancel, and formula (23) becomes:

$$(24)\ dg_2 = \frac{dg_1 \times \text{counts}_1}{\text{counts}_2}.$$

EXAMPLE: *Without changing roving what size draft gear must we use to spin 30s on a frame that has been spinning 26s with a 34-tooth draft gear?*

Using formula (24):

$$\text{required draft gear} = \frac{34 \times 26}{30} = 29.5. \quad \text{Answer: 29 or 30 teeth.}$$

91. A draft of 11.5 is being inserted by a 26-tooth draft gear. What gear is required to insert a draft of 10.4?

92. We are spinning 40s from 5.25-hank roving using a 28-tooth draft gear. What gear must we use to spin 36s from 4.2-hank roving?

93. 30s is being spun with a draft of 8 by a 36-tooth draft gear. What gear on the same frame will produce a draft of 9.5?

94. We have been spinning 38s with a 40-tooth draft gear. What draft gear will spin 32s without a change of roving?

95. A 50-tooth draft gear produces 44.4s from 2.22-hank roving doubled. What gear on the same frame will produce 55s from 2.81-hank roving doubled?

96. A 38-tooth draft gear has been used in spinning 50s from 2.6-hank roving doubled. What gear shall we use in spinning 54s from 2.6-hank roving doubled?

97. A draft of 10.93 is produced by a draft gear of 41 teeth. What gear will give a draft of 9.93?

98. If the hank roving remains the same, from one of the three preceding formulas prove that:

$$\text{required draft gear} = \frac{\text{present draft gear} \times \text{wt. of 120 yds. of required yarn}}{\text{wt. of 120 yds. of present yarn}}.$$

99. We test 120 yards of yarn from a frame with a 32-tooth draft gear. It weighs 32.26 grains which is 1.07 grains too light. What draft gear should we use?

100. The weave room requests the spinning room to increase the weight of filling $4\frac{1}{2}\%$. If a 41-tooth draft gear is now in use, what size draft gear shall be used to comply with the weave room's request?

LAY CHANGE GEAR

The lay gear (L, figure 2) regulates the up and down speed of the ring rail, and consequently regulates how closely the coils of yarn on the bobbin shall lie. The *lay constant* of the frame can be calculated from the frame, but it is hardly practical to do so because of the variation in humidity, temperature, twist, staple, etc. It can be calculated in the same manner that it was calculated for the roving frame. From the lay constant the following fairly reliable formula can be worked out and used in making large changes in the size of yarn run.

$$(24)\quad \text{required lay gear} = \frac{\text{present lay gear} \times \sqrt{\text{present counts}}}{\sqrt{\text{required counts}}}.$$

101. A 40-tooth lay gear is laying 36s yarn properly. What gear shall we use for 25s?

102. A 42-tooth lay gear is laying 30s yarn properly. What gear shall be used for 50s?

103. A 22-tooth lay gear is laying 50s smoothly on the bobbin. What gear shall we use for 16s?

R.P.M. OF CYLINDER AND SURFACE SPEED OF FRONT ROLL

104. Letting a stand for the driving pulley on the overhead shaft and b for the driven pulley on the frame, work out a formula for the R.P.M. of the cylinder of figure 2.

105. If the speed and the diameter of the overhead driving pulley are 400 R.P.M. and 30″, respectively, and the driven pulley on the frame is 12″ in diameter, what is the speed of the cylinder?

106. If the speed of the overhead pulley is 400 R.P.M. and its diameter 30″, and the driven pulley on frame is 19″, what is the speed of the cylinder?

107. If the overhead pulley makes 350 R.P.M. and the cylinder is to make 585 R.P.M., what must be the diameter of the frame pulley if the overhead pulley is 26″ in diameter?

108. Work out a formula for the surface speed of the front roll of figure 2, starting with the R.P.M. of the cylinder.

109. On the frame in figure 2 with the combination shown in problem 30 we wish to spin 30s standard warp twist. What will be the R.P.M. of the front roll if the speed of the cylinder is 1226.5 R.P.M.? *Hint:* Use the formula from problem 108.

110. On the frame in figure 2 with the combination shown in problem 31 we wish to spin 36s standard warp twist. We wish to have the front roll make 140 R.P.M. What must be the speed of the cylinder to obtain this front roll speed?

Production, Production Constants and Percent of Production

It is evident that the inches of yarn produced per minute per spindle equals the front roll surface speed in inches per minute less whatever percent the yarn contracts during twisting:

111. Work out the following formulas for 100% production of yarn in 10 hours, letting *fr* stand for front roll and neglecting the contraction due to twisting:

(25) $$\text{production (in hanks) per spindle per 10 hrs.} = \frac{10 \times 60 \times 3.1416 \times \text{dia.}\,fr \times \text{R.P.M.}\,fr}{36 \times 840}.$$

112. From formula (25) work out the following formulas for 100% production:

(26) $$\text{production (in hanks) per spindle per 10 hrs. with } 1'' \text{ front roll} = .062 \times \text{R.P.M.}\,fr.$$

(27) $$\text{production (in hanks) per spindle per 10 hrs. with } 1\tfrac{1}{8}'' \text{ front roll} = .07 \times \text{R.P.M.}\,fr.$$

.062 and .07 are called the *production constants* of 1″ and $1\frac{1}{8}$″ rolls, respectively, for 10 hrs.

113. Work out the following formulas for 100% production:

(28) $$\text{production (in lbs.) per spindle per 10 hrs. with } 1'' \text{ front roll} = \frac{.062 \times \text{R.P.M.}\,fr}{\text{counts}}.$$

(29) $$\text{production (in lbs.) per spindle per 10 hrs. with } 1\tfrac{1}{8}'' \text{ front roll} = \frac{.07 \times \text{R.P.M.}\,fr}{\text{counts}}.$$

Allowances. In addition to the deduction that must be made for contraction due to twisting an allowance must be made for stoppages due to cleaning, doffing, etc. The combined allowances for contraction and stoppages vary according to staple of cotton and many other conditions.

114. What is the production in hanks and lbs. for 10 hrs. of 50s warp yarn standard twist by a 1″ front roll making 103 R.P.M. if the allowance for these counts and twist is 5%?

115. What is the production in hanks and lbs. for 10 hrs. of 15s warp yarn standard twist by a 1″ front roll making 144 R.P.M. if the allowance for this counts and twist is 10%?

116. If a 300-spindle frame with a 1″ front roll making 95 R.P.M. produces 26.5 lbs. of 65s warp in 10 hrs., what is its percent of production? What allowance should be made for this frame when running this counts and twist?

117. To maintain 83% production on 13s filling, what must be the production for 10 hrs. in hanks and lbs. of 12 frames with 112 spindles to a side if the 1″ front roll makes 168 R.P.M.?

118. To maintain 82% production on 10s filling, what must be the production for 10 hrs. in hanks and lbs. of 6 frames of 256 spindles each if the $1\frac{1}{8}$″ front roll makes 159 R.P.M.?

119. What must be the speed of the pulley on the cylinder shaft of the 300-spindle frame in figure 2 with the combination in problem 30 if it is to produce 65.4 lbs. of 30s warp in 10 hrs., allowing 9% for stoppage and contraction?

Length of Time a Bobbin in Creel will Last

For the formula and method by which it is worked out refer to this same subject under fly frames in chapter IX.

120. How long will a 10-oz. bobbin of 10-hank roving last in the creel of a spinning frame if the draft is 6 and the diameter and speed of the front roll is 1″ and 120 R.P.M.?

CHAPTER XI

TWISTER, SPOOLER AND WARPER CALCULATIONS

Twisters

The twist constant can be found for a twister in exactly the same manner as found for a spinning frame.

Note: Review, if necessary, ply yarn calculations.

Example: *If the twist constant of a twister is* 840.34, *what gear shall be used for producing* 50s 2-*ply soft twist?*

Counts produced $= \frac{50}{2} = 25$. Twists per inch $= 4 \times \sqrt{25} = 20$.

Twist gear $= \frac{840.34}{20} = 42.02$. Answer: 42-tooth twist gear.

Problems:

1. If the twist constant of a twister is 713.00, what gear shall be used for producing 48s 3-ply medium twist?

2. What gear shall be used for producing 50s 5-ply hard twist if the twist constant is 585.00?

3. A fancy yarn is to be medium twisted from one end of 24s, one end of 36s and one end of 72s. What gear shall be used if the twist constant is 620?

4. If a 30-tooth twist gear has been producing 32s 2-ply soft twist, what gear shall we use for 27s 3-ply soft twist?

5. If a 32-tooth twist gear has been producing 32s 2-ply hard twist, what gear shall we use for 48s 3-ply soft twist?

6. Make a diagram of a twister in your mill and compute the twist constant. Check this with the twist gear and ply yarn being run.

7. Using formula (25) of the spinning frame, prove that the 100% production constant of a twister with a $1\frac{1}{2}''$ diameter front roll is .0935.

8. How many pounds per spindle in 10 hrs. of 10s 3-ply soft twist will be produced by a twister, the $1\frac{1}{2}''$ front roll of which makes 119 R.P.M., allowing 15% for stoppages, etc., for this counts and twist?

9. What percent of production is being gotten from a 120-spindle twister, the $1\frac{1}{2}''$ front roll of which makes 88 R.P.M., if it produces 207 lbs. of 20s 5-ply in 10 hrs.?

10. To secure 90% production, how many pounds of 36s 2-ply must be produced in 10 hrs. by a 200-spindle twister if its $1\frac{1}{2}''$ front roll makes 75 R.P.M.?

Spoolers

Your study thus far should enable you to work out all the necessary formulas for spoolers.

11. Make a diagram of the gearing of a spooler in your mill.

12. Work out a formula for the traverse gear showing the size of gear needed for any length of spool (length of traverse).

13. Work out the following formula for changing from one length of traverse to another length of traverse:

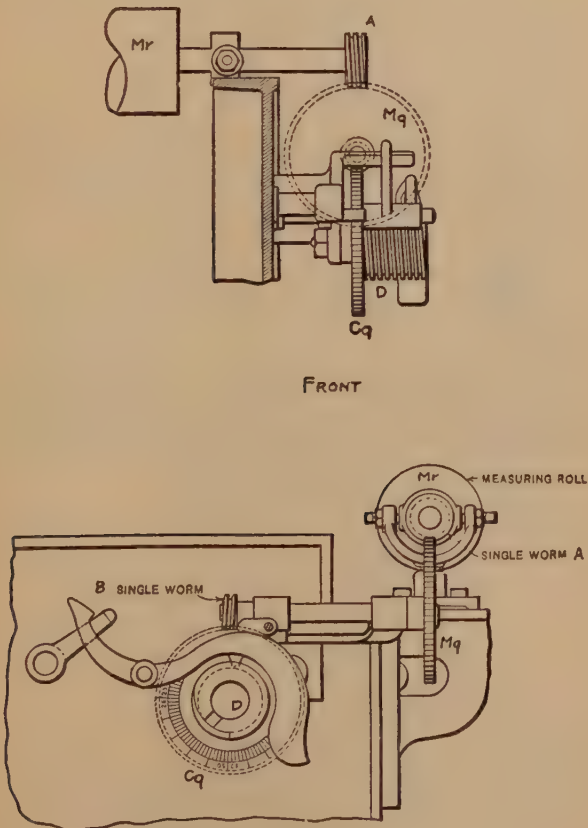
$$(30)\quad \text{required traverse gear} = \frac{\text{present traverse gear} \times \text{required length of traverse}}{\text{present length of traverse}}.$$

14. On a certain spooler, a 57-tooth gear is running $5''$ spools with a traverse of $4\frac{3}{4}''$. What gear shall we use to run $6''$ spools having a traverse of $5\frac{3}{4}''$?

15. If a 63-tooth gear gives a traverse of $5\frac{1}{4}''$, what gear will give a traverse of $6\frac{5}{8}''$?

WARPERS

Figure 1 shows one make of the clock and gearing of a warper.



FRONT

RIGHT END

Figure 1. WARPER GEARING

Let Mr stand for the measuring roll; A and B for the single worms; Mg for the teeth in the measuring (or wrap) gear; Cg for the teeth in the clock gear; D for the clock worm. It will be observed that the mechanism can be so adjusted that the dog will drop into the slot in D at any full revolution of D, thereby stopping the warper. Let y stand for the number of yards of warp wound on the beam during any revolution of the clock.

16. Prove that:

$$(31)\ y = \frac{Cg \times Mg \times \text{cir. } Mr}{36}.$$

17. (a) If the circumference of Mr is 12″, Mg has 105 teeth and Cg has 100 teeth, how many yards are wound on the beam during one revolution of the clock gear?

(b) If the parts are as shown in (a), how many threads of D must the dog be set back to give a 7000-yard beam?

18. If it is desired to have the yardage on the beams multiples of 3000 yards and the measuring roll is 9″ in circumference and the clock gear has 100 teeth, how many teeth must the wrap gear have?

CHAPTER XII

LOOM CALCULATIONS

PICKS PER MINUTE

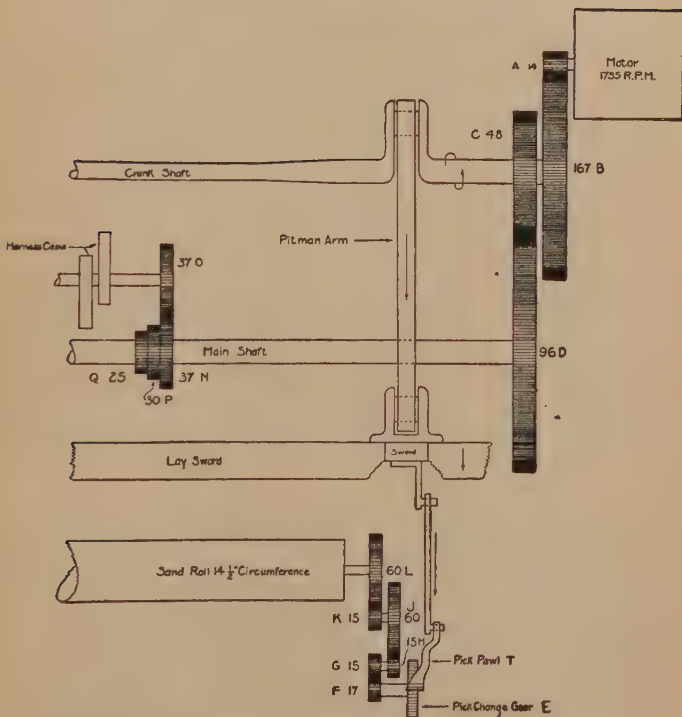


Figure 1. TAKE-UP GEARING OF A LOOM WITH A PICK PAWL TAKE-UP

(Courtesy of Parker School District, Greenville, S.C.)

Problems and Questions:

1. While the crank shaft in figure 1 is making one complete revolution, how many picks does the loom put into the cloth? Why?

2. If the speed of the motor in figure 1 is as shown, calculate the number of picks per minute that the loom makes.

3. Suppose that instead of gear *B* (figure 1) we have a $14\frac{1}{2}''$ pulley which is driven by an overhead pulley making 150 R.P.M. What size pulley must we use overhead to obtain at least the number of picks found in problem 2?

4. How many picks per minute does the loom in figure 2 make?

5. If gear *B* (figure 2) were replaced by a 15″ pulley driven by an overhead driving pulley making 150 R.P.M., what should be the size of the driving pulley to obtain the picks per minute found in problem 4?

6. How many picks per minute are made by the loom in figure 3?

Picks per Inch and Pick Change Gears

Consider figure 1, which represents a loom equipped with a pick pawl take-up motion. The pick pawl, *T*, is so arranged that each time the lay sword comes forward the pick pawl moves the pick change gear, *E*, forward one tooth. *E* is a ratchet gear; therefore, we can consider the pick pawl, *T*, a *one-tooth driver gear*, because a one-tooth gear in making a complete revolution would move the gear that it meshes with only the distance of one tooth. Since the pick pawl moves for-

ward and then back each time that the lay sword makes a pick, we can say that the R.P.M. of the one-tooth gear, T, is the same as the picks per minute of the loom. Let *ppm* stand for the number of picks per minute. Therefore:

$$(1)\ \text{R.P.M. of } T = ppm.$$

Now let us consider the sand roll. Let S stand for sand roll. Let *ppi* stand for the number of picks per inch. The number of picks per minute that S takes up is the number of picks per inch multiplied by the number of inches the surface of S travels in a minute. In other words,

$$(2)\ ppm = ppi \times \text{surface speed of } S.$$

We also know from our discussion of R.P.M. and surface speeds that:

$$(3)\ \text{Surface speed of } S = \text{R.P.M. of } S \times \text{circumference of } S.$$

Therefore, substituting the right side of equation (3) in place of surface speed of S in equation (2), we have:

$$(4)\ ppm = ppi \times \text{R.P.M. of } S \times \text{cir. of } S.\ \text{Therefore:}$$

$$(5)\ \text{R.P.M. of } S = \frac{ppm}{ppi \times \text{cir. of } S}.$$

Now let us consider the train of gears. Let each letter stand for the number of teeth in each gear. Notice that gear L turns at the same speed as S. From our study of gear trains and omitting the word "of" after R.P.M., S.S., etc., we know that:

$$(6)\ \frac{\text{R.P.M. } T}{\text{R.P.M. } S} = \frac{E \times G \times J \times L}{T \times F \times H \times K}.$$

Substituting from equations (1) and (2) into equation (6) we have:

$$(7)\ \frac{ppm}{\dfrac{ppm}{ppi \times \text{cir. } S}} = \frac{E \times G \times J \times L}{T \times F \times H \times K}.$$

Canceling the right side of equation (7) we have:

$$(8)\ ppi \times \text{cir. } S = \frac{E \times G \times J \times L}{T \times F \times H \times K}.$$

From this we see that:

$$(9)\ ppi = \frac{E \times G \times J \times L}{T \times F \times H \times K \times \text{cir. } S}.$$

Contraction after Leaving Sand Roll. The sand roll keeps the cloth on the loom in a state of tension. But after the cloth leaves the sand roll and starts to wind up on the cloth roll it is no longer under tension, and the warp draws up. Therefore, there are more picks per inch in the finished cloth than there are in the cloth before it has left the sand roll. Hence, equation (9) is true only for the cloth before it leaves the sand roll. We know that the smaller the sand roll, the slower the cloth passes through the reed, and consequently the greater the picks per inch. Thus, we see that to make equation (9) true of the cloth after it leaves the sand roll, we must subtract a slight amount from the circumference of S. Experience has shown that, on the average, about $2\frac{1}{2}\%$ is the right amount to deduct from the circumference of S. Therefore, equation (9) to be true of the cloth after it leaves the sand roll must be:

$$(10)\quad ppi = \frac{E \times G \times J \times L}{T \times F \times H \times K \times (\text{cir. } S - 2\frac{1}{2}\% \text{ of cir. } S)}.$$

From this we see that the formula for E, the *driven* pick change gear, is:

$$(11)\quad E = \frac{T \times F \times H \times K \times ppi \times (\text{cir. } S - 2\frac{1}{2}\% \text{ of cir. } S)}{G \times J \times L}.$$

To shorten our formula we can write it thus:

$$(12)\quad E = \frac{T \times F \times H \times K \times ppi \times .975 \times \text{cir. } S}{G \times J \times L}.$$

EXAMPLE: *The loom in figure* 1 *is to make cloth with* 60 ppi. *What size pick change gear must we use?*

$$.975 \times 14.5 = 14.14.$$

$$E = \frac{1 \times 17 \times 15 \times 15 \times 60 \times 14.14}{15 \times 60 \times 60} = \frac{240.38}{4} = 60.0.$$

The pick change gear must have 60 teeth.

PROBLEMS: *What size pick change gear must be used on the loom in figure* 1 *to obtain the following?*

7. 18 picks per inch.

8. 20 picks per inch.

9. Using equation (10) find how many picks per inch will be inserted by a 17-tooth pick gear.

Pick Constants

The use of *pick constants* greatly shortens the figuring of picks per inch and pick change gears. From equation (12) we see that:

$$(13)\quad \frac{E}{ppi} = \frac{T \times F \times H \times K \times .975 \times \text{cir. } S}{G \times J \times L}$$
$$= \frac{1 \times 17 \times 15 \times 15 \times 14.14}{15 \times 60 \times 60} = 1.$$

Therefore, we see the quotient of E *divided* by ppi always equals a certain fixed number. This number is called the *pick constant.* Therefore, the pick constant of this loom is 1. Letting pc stand for pick constant and pg stand for pick change gear, we obtain from formula (13) the following useful formulas:

$$(14)\quad pc = \frac{pg}{ppi}, \text{ and } (15)\quad pg = pc \times ppi.$$

EXAMPLE: *What pick gear shall we use on the loom in figure* 1 *to obtain* 76 *picks per inch?*

Using equation (15): pick gear $= pc \times ppi = 1 \times 76 = 76.$ Answer: 76 teeth.

PROBLEMS:

10. What size pick gear shall we use to obtain 29 picks per inch on the loom in figure 1?

11. (*a*) If the pick constant of a loom with a driven pick gear (as in figure 1) is 2, what size pick gear shall we use to obtain $9\frac{1}{2}$ picks per inch?

(*b*) If the pick constant of a loom with a driven pick gear is 1.5, what gear shall we use to obtain 30 picks per inch?

12. (*a*) On a loom with a driven pick gear, does increasing the pick gear increase or decrease the picks per inch?

(*b*) Therefore, is a driven pick gear directly or inversely proportional to the picks per inch?

13. If the pick constant of a loom with a driven pick gear is 1.5, what gear shall we use for 31 picks per inch if the yarn is slightly light weight?

Figure 2 shows a loom equipped with a single worm take-up motion. Each time the worm, *W*, makes one revolution, it takes up one single tooth of the gear, *H*.

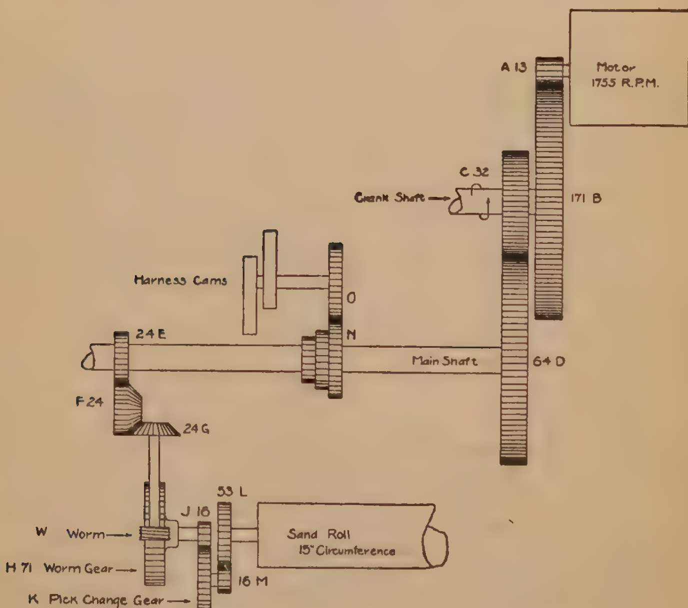


Figure 2. TAKE-UP GEARING OF A LOOM WITH A SINGLE WORM TAKE-UP

(Courtesy of Parker School District, Greenville, S.C.)

14. (*a*) What effect do gears E, F and G have upon the R.P.M. of W?

(*b*) What is the relation of the R.P.M. of W to the R.P.M. of the crank shaft?

(*c*) Therefore, what is the relation of the R.P.M. of W to the picks per minute?

15. Following the same method used in working out formula (13) for the loom in figure 1, work out a formula for the pick constant of the loom in figure 2. Then substitute the figures shown in figure 2 and find the pick constant of the loom.

16. Using problem 15, find the pick gear on the loom in figure 2 required to obtain 20 picks per inch.

17. Find the pick gear on the loom in figure 2 required to obtain 73 picks per inch.

The loom in figure 3 is equipped with a double worm take-up motion. One turn of the double worm, P, takes up two teeth of the worm gear, G.

18. Work out a formula for the pick constant of the loom in figure 3. Then substitute the figures from figure 3 in the formula and find the pick constant of this loom.

19. On the loom in figure 3, what pick gear shall we use to obtain 29 picks per inch?

20. What would you do in the following case: The smallest size pick gear that can be used for L (figure 3) is 10 teeth, because of the pitch of the teeth and the size of the hole through the gear. A leno weave of 16 picks per inch is to be woven?

21. (*a*) If we use a 28-tooth gear for K (figure 3), what will the pick constant become?

(*b*) What pick gear shall we use for the 16-pick leno of problem 20 if K has 28 teeth?

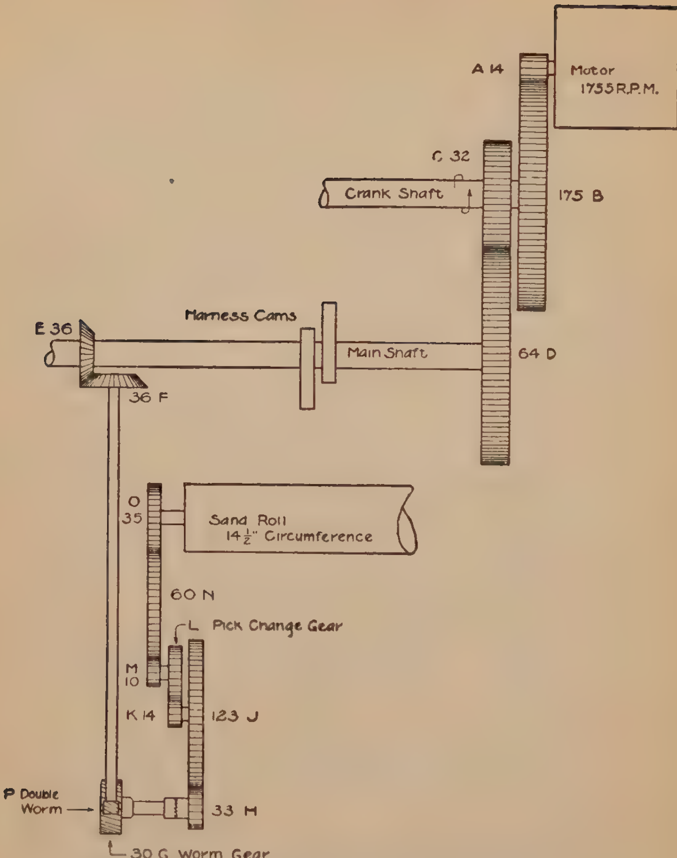


Figure 3. TAKE-UP GEARING OF LOOM WITH DOUBLE WORM TAKE-UP

(Courtesy of Parker School District, Greenville, S.C.)

22. (*a*) If K (figure 3) remains 14 teeth and we use an 82-tooth gear for J, what will the pick constant become?

(*b*) What pick gear would we then use to obtain 16 picks per inch?

23. Using formula (14), find the pick constant of a loom that is producing cloth of 33 picks per inch with a 22-tooth driven pick gear.

24. A 38-tooth driven pick gear is putting 21 picks per inch in the cloth. What is the pick constant?

25. Suppose that instead of the *driven* gear L (figure 3) being the pick change gear, the *driver* gear K is the pick change gear. Rearrange the formula you worked out in problem 18 into a formula for the pick constant using K as the pick change gear and giving L 11 teeth. Then substitute the figures from figure 3 into the formula and find the pick constant.

26. Now show that when the pick change gear is a *driver* gear, the following formulas are true:

$$(16)\ pc = pg \times ppi, \text{ and } (17)\ pg = \frac{pc}{ppi}.$$

27. Using the conditions set up in problems 25 and 26, find the driver pick gear required to obtain 8 picks per inch.

28. Using the conditions set up in problems 25 and 26, find the driver pick gear required to obtain 30 picks per inch.

Suppose we wish to change from the cloth being made at present on a loom to a cloth with a different number of picks per inch, and we wish to find the *driven* pick gear required for the new cloth:

Using equation (14): $pc = \frac{\text{present } pg}{\text{present } ppi}$, also $pc = \frac{\text{required } pg}{\text{required } ppi}$.

Since the left sides are equal, the right sides must be equal.

Therefore, $\frac{\text{present } pg}{\text{present } ppi} = \frac{\text{required } pg}{\text{required } ppi}$. Therefore:

$$(18)\ \text{required } pg = \frac{\text{present } pg \times \text{required } ppi}{\text{present } ppi}.$$

29. If a loom is making 34 picks per inch with a 20-tooth driven pick gear, what pick gear will make 26 picks per inch? Use formula (18).

30. If a loom is making 42 picks with a 35-tooth driven pick gear, what pick gear will make 30 picks per inch?

31. Prove that if the loom has a *driver* pick gear:

$$(19)\quad \text{required } pg = \frac{\text{present } pg \times \text{present } ppi}{\text{required } ppi}.$$

32. If a loom is making 45 picks per inch with a 16-tooth driver pick gear, what gear must we use to obtain 32 picks per inch?

33. A 20-tooth driver pick gear is making 60 picks per inch. What gear will make 80 picks per inch?

34. Make a diagram of the take-up motion of a loom in your mill. Find the pick constant.

Cam Gearing

There are many kinds of cam arrangements. The simplest arrangement is to place the cams directly on the cam or main shaft. Looking at figure 3 we see that R.P.M. of C = 2 R.P.M. of D. Hence, a cam on the cam shaft would be up every two picks, which is the condition required for plain weaving with two harnesses.

It is therefore evident that when it becomes necessary to have harnesses up (or down) only every three, four, five and six picks as in weaving twills and sateens, another arrangement is necessary. Figure 2 shows one arrangement of an auxiliary cam shaft, to which the cams are attached, adaptable to any of the above weaves. It is evident that with a weave requiring harnesses up (or down) every *two* picks, C (figure 2) must revolve *twice* as fast

as O; requiring harnesses up (or down) every *three* picks, C must revolve *three* times as fast as O; up (or down) every *four* picks, *four* times as fast, and so on. Hence:

R.P.M. of C = number of harnesses × R.P.M. of O. Also: $\frac{\text{R.P.M. of } C}{\text{R.P.M. of } O} = \frac{D \times O}{C \times N}$. Combining these two equations we have:

$\frac{\text{number of harnesses} \times \text{R.P.M. of } O}{\text{R.P.M. of } O} = \frac{64 \times O}{32 \times N}$. Canceling we have:

$$(20)\quad \text{number of harnesses} = \frac{2 \times O}{N}, \text{ or}$$

$$(21)\quad N = \frac{2 \times O}{\text{number of harnesses}}.$$

N has three "steps" as shown. N and the auxiliary cam shaft are so arranged that O can be brought into mesh with any of the steps on N. O can be changed.

EXAMPLE: *If* O *has* 30 *teeth, how many teeth must the largest step in* N *have to make a* 2-*harness plain weave?*

Using equation (21): $N = \frac{2 \times 30}{2} = 30.$

PROBLEMS:

35. If O has 30 teeth, how many teeth must the middle step of N have to weave a 3-harness twill?

36. If O has 30 teeth, how many teeth must the smallest step of N have to weave a 4-harness twill?

37. Work out a formula for O.

38. If the steps of N remain as in the preceding example and as in problems 35 and 36, and the loom is to weave a 5-harness sateen, what is the smallest number of teeth that O can have to make this weave and with what step on N must O mesh?

39. If N is to remain as in the preceding example and problems, what is the least number of teeth O

may have and with what step of N must O mesh to weave a 6-harness sateen?

40. Suppose we wish to have enough steps on N to weave everything from 2 to 6-harness weaves without changing O. How many steps on N will be needed? What will be the number of teeth in each step of N to keep the number of teeth in O as small as possible? How many teeth will there be in O?

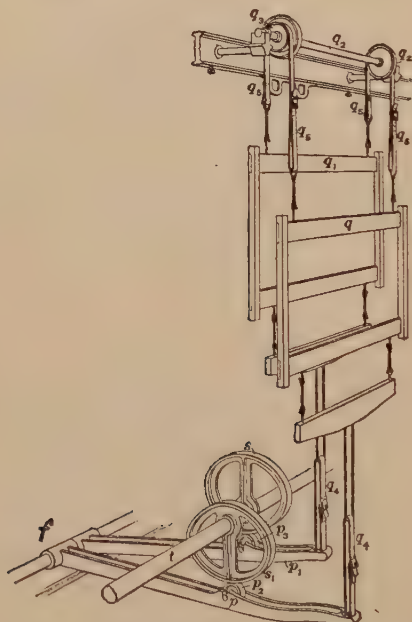


Figure 4. SHEDDING MOTION OF A LOOM
(Courtesy and special permission of International Textbook Co.)

41. If the looms in your weave room are equipped to make twills, make a diagram of the gearing and

calculate the sizes of gears necessary to make everything up to 6-harness work.

Throw of Cams. Consider figure 4. From our study of levers we see that the treadle is a lever, the shed of the harness is the resistance distance; the *throw* (or difference between the largest and smallest radius) of the cam is the power distance and the center of the stud, f, is the fulcrum. Hence, considering the front harness, q:

$$\frac{\text{throw of cam}}{\text{shed}} = \frac{\text{length of treadle } f \text{ to } p_2}{\text{total length of treadle}}.\quad \text{Therefore:}$$

$$(22)\quad \textbf{throw of cam} = \frac{\textbf{length of treadle } f \textbf{ to } p_2 \times \textbf{shed}}{\textbf{total length of treadle}}.$$

42. What must be the throw of the cam to obtain a shed of 3″ if the treadle is 30″ long and the point of contact of the cam and treadle is 18″ from the center of the stud?

43. On a certain loom the points of contact of the cams and the treadles are 15″ from the center of the stud. The front harness requires a shed of 4″ and the back harness needs a shed of at least $4\frac{1}{2}$″. What must be the throw of each cam if the front harness treadle is 22″ long and the back harness treadle is 20″ long?

44. On another loom the points of contact of the cams and treadles are 15″ from the center of the stud. The front harness requires a shed of $3\frac{3}{4}$″ and the back harness a shed of 5″. The front treadle is 24″ long and the back treadle is 23″ long. Find the required throw of each cam.

Production and Percent of Production

45. If a loom makes 150 picks per minute and is making cloth of 50 picks per inch:

(*a*) How many inches does it produce in 1 minute?
(*b*) How many yards does it produce in 60 minutes?
(*c*) How many yards does it produce in 10 hours?

46. Hence, prove the following formula for 100% production:

$$(23)\ \text{production (in yds.) per 10 hrs.} = \frac{100 \times \text{picks per minute}}{6 \times \text{picks per inch}}.$$

47. If a loom is run 164 picks per minute and making 48 pick goods, how many yards will the loom weave in 10 hours?

48. How many yards of 34″ 1.65 64 × 112 moleskin will a loom running 164 picks per minute weave in 55 hours, allowing 10% for stoppage?

49. How many yards of 37″ 3.95 68 × 40 drills will 120 looms running 164 picks per minute weave in 55 hours if the stoppage is $4\frac{1}{2}$%?

50. How many yards will 300 looms weave in 10 hours on 30″ 2.50 72 × 60 drills, if the speed of the loom is 162 picks per minute and the looms average running 96% of the time?

51. If 100% production per loom is $4\frac{1}{2}$ yards per hour, how many yards of first-quality cloth will 380 looms weave in 5 weeks, 55 hours per week, allowing 5% for stoppage and 4% for second-quality cloth?

52. If a loom will weave 3 inches of a certain style cloth in one minute, how many yards will 120 looms weave in 3 weeks, 55 hours per week, if the stoppage amounts to 4%?

53. If 388 looms weave 1906 cuts (60 yards per cut) in 6 days and 51.72 yards per loom per day is 100% production, what percent do they weave?

54. On a certain style goods 62 yards per loom per day is 100% production. 500 looms wove 3038 cuts (60 yards per cut) in 6 days. What was the percent of production?

55. Find 96% production in yards for 106 looms run 55 hours at 164 picks per minute on $29\frac{1}{2}''$ 3.33 34×34 osnaburg.

56. How many yards of 38″ 2.85 96×64 drills will a loom weave in 10 hours, if run 160 picks per minute, allowing 8% for stoppage?

57. On a certain style cloth 55 yards per loom per day is 100% production. It is desired to make 114,950 yards of this cloth in 4 weeks, $5\frac{1}{2}$ days per week. How many looms will be required to make it, allowing 5% for stoppage?

58. If 50 yards per day per loom is 100% production, how many yards of first-quality cloth will 200 looms weave in 6 weeks, $5\frac{1}{2}$ days per week, if the loom stoppage is 6% and 4% of the cloth is second quality?

59. How many yards of first-quality cloth will 100 looms running 160 picks per minute on 56-pick goods weave in 4 weeks, 55 hours per week, allowing 6% for stoppage and 5% for second-quality cloth?

60. How many looms will be required to weave 353,628 yards of first-quality cloth in 6 weeks, 55 hours per week, if 60 yards per loom in 10 hours is 100% production, allowing 5% for loom stoppage and 6% for second-quality cloth?

61. How many 60-yard cuts per week of 55 hours will be 96% production for 20 looms making 36″ 2.85 48×48 sheeting if the looms run 164 picks per minute.

ANSWERS

PART ONE

Chapter I, PROBLEM **1** 122, One hundred twenty-two. **2** 236, Two hundred thirty-six. **3** 999, Nine hundred ninety-nine. **4** 1,122, One thousand one hundred twenty-two; or Eleven hundred twenty-two. **5** 2,236, Two thousand two hundred thirty-six; or Twenty-two hundred thirty-six. **6** 9,999, Nine thousand nine hundred ninety-nine; or Ninety-nine hundred ninety-nine. **7** 11,122, Eleven thousand one hundred twenty-two. **8** 32,236, Thirty-two thousand two hundred thirty-six. **9** 99,999, Ninety-nine thousand nine hundred ninety-nine. **10** 111,122, One hundred eleven thousand one hundred twenty-two. **11** 532,236, Five hundred thirty-two thousand two hundred thirty-six. **12** 999,999, Nine hundred ninety-nine thousand nine hundred ninety-nine. **13** 1,111,122, One million one hundred eleven thousand one hundred twenty-two. **14** 6,532,236, Six million five hundred thirty-two thousand two hundred thirty-six. **15** 9,999,999, Nine million nine hundred ninety-nine thousand nine hundred ninety-nine. **16** 11,111,122, Eleven million one hundred eleven thousand one hundred twenty-two. **17** 76,532,236, Seventy-six million five hundred thirty-two thousand two hundred thirty-six. **18** 99,999,999, Ninety-nine million nine hundred ninety-nine thousand nine hundred ninety-nine. **19** 143,256,793, One hundred forty-three million two hundred fifty-six thousand seven hundred ninety-three. **20** 650,763,941, Six hundred fifty million seven hundred sixty-three thousand nine hundred forty-one. **21** 769,832,456, Seven hundred sixty-nine million eight hundred thirty-two thousand four hundred fifty-six. **22** 3,896,743,226, Three billion eight hundred ninety-six million seven hundred forty-three thousand two hundred twenty-six. **23** 11,456,666,732, Eleven billion four hundred fifty-six million six hundred sixty-six thousand seven hundred thirty-two. **24** 27,567,891,429, Twenty-seven million five hundred sixty-seven million eight hundred ninety-one thousand four hundred

twenty-nine. **25** One thousand one. **26** Ten thousand one. **27** One hundred thousand. **28** Five hundred thousand nine. **29** One million. **30** Nine hundred million. **31** Nine hundred one million twenty thousand three hundred four. **32** Nine billion two. **33** One hundred billion one million one thousand one. **34** 1,294,512. **35** 1,325,856. **36** 2,682,730. **37** 1,137,651. **38** 112,024. **39** 11,222,741. **40** 178,508. **41** 1,384,757. **42** 440,560. **43** 1,000,234. **44** 5,463,547. **45** 164,507. **46** 2,837,903. **47** 5,107,038. **48** 437,168. **49** 175,104. **50** 144,808. **51** 654,785. **52** 36,260,001. **53** 1,375,000. **54** 56,583,000. **55** 157,763,000.

Chapter II, Problem 1 5. **2** 7. **3** 9. **4** 11. **5** 13. **6** 15. **7** 17. **8** 18. **9** 15. **10** 21. **11** 24. **12** 27. **13** 85. **14** 79. **15** 78. **16** 89. **17** 189. **18** 999. **20** 1940 looms. **21** 2329 yards. **22** 1818 pounds. **23** 1920 looms. **24** 3450 yards. **25** 3281 pounds. **26** $22,441. **27** 422,664 yards. **28** 179. **29** 211,400 drop wires. **30** 10,287 pounds. **31** 111,672 pounds. **32** 205,772 pounds of yarn; 3163 pounds of waste.

Chapter III, Problem 1 4. **2** 4. **3** 11. **4** 12. **5** 15. **6** 23. **7** 63. **8** 112. **9** 12. **10** 43. **11** 25. **12** 41. **13** 0. **14** 4. **15** 7. **16** 6. **17** 4. **18** 5. **19** 7. **20** 9. **21** 9. **22** 6. **23** 15. **24** 11. **25** 10. **26** 30. **27** 44. **28** 101. **29** 250 more. **30** 674 yards. **31** 4420 pounds. **32** 24,730 pounds. **33** 6 pounds. **34** 9 pounds. **35** 3 yards. **36** 49 pounds. **37** 3013 pounds. **38** 158 years. **39** 33 years. **40** $1502 more. **41** 292,430 yards. **42** 8212 yards. **43** 453 pounds.

Chapter IV, Problem 1 30. **2** 36. **3** 42. **4** 24. **5** 27. **6** 36. **7** 42. **8** 70. **9** 25. **10** 80. **11** 9. **12** 5. **13** 0. **14** 0. **15** 0. **16** 36. **18** 22. **19** 36. **20** 39. **21** 69. **22** 28. **23** 88. **24** 1107. **25** 3192. **26** 2523. **27** 72,968. **28** 66,612. **29** 89,991. **30** 414,425 pounds. **31** 720 ounces. **32** $33,000. **33** 62,000 yards. **34** 984 dents. **35** 44,620 bobbins. **36** 640 ounces. **37** 280,000 yards. **38** 133,000 pounds. **39** 12,000 gallons water; 11,200 pounds starch; 1760 pounds sizing tallow. **40** 114,240 yards. **41** 1,484,520 eyes. **42** 770,000. **43** 1620 cents. **44** $208. **45** $16,800. **46** 7,591,000 knots. **47** 181,440 ends.

Chapter V, Problem 1 2 pounds. **2** 4 yards. **3** 3. **4** 8 yards. **5** 8. **6** 2 boxes. **7** 7. **8** 9. **9** 2. **10** 1. **11** 7 bobbins. **12** 1. **13** 6. **14** 9. **15** 10. **16** 9. **17** 1. **18** 1. **19** 71. **20** 132. **21**

234. **22** 811. **23** 1470. **24** 206. **25** 199. **26** 1005. **27** 239 pounds. **28** 288. **29** 90,040. **30** 90,919. **31** 18 looms. **32** 43 weeks. **33** 36 inches. **34** 89 pounds. **35** 268 frames. **36** 50. **37** 40. **38** 25. **39** 20. **40** 10. **41** 5. **42** 4. **43** 2. **44** 1. **45** 3 days. **46** \$1100. **47** 4 pounds. **48** 50,400 yards. **49** 50 days. **50** 12 ounces. **51** 48 yards. **52** 1060 yards. **53** 53 spinners. **54** 84 looms. **55** 203 days. **56** 376 ends. **57** 200 pounds. **58** 48 ends. **59** 1 hour. **60** 844 bobbins. **61** 7204 bobbins. **62** 7264 yards. **63** 342 ends. **64** 278 ends. **65** 3624 ends. **66** \$450. **67** 32 kettles. **68** 125 bales. **69** 15,000 pounds. **70** 5 pounds. **71** 2 twists per inch.

Chapter VI, PROBLEM **1** 2, 2, 2, 3, 5. **2** 2, 2, 2, 2, 2, 2, 2. **3** 2, 3, 5, 5. **4** 5, 5, 7. **5** 2, 3, 5, 7. **6** 3, 97. **7** 2, 2, 3, 3, 3, 5. **8** Prime number. **9** 2, 2, 2, 3, 5, 7. **10** 7, 11, 13. **11** 2, 2, 2, 3, 11, 13. **12** 2, 2, 2, 3, 7, 11, 17. **13** 48. **14** 24. **15** 90. **16** 126. **17** 1001. **18** 144. **19** 360. **20** 1092. **21** 720. **22.** 504.

Chapter VII, PROBLEM **49** $10\frac{11}{16}$. **50** $225\frac{37}{201}$. **51** $116\frac{141}{1000}$. **52** $17\frac{222}{2000}$. **53** $\frac{57}{16}$. **54** $\frac{1680}{840}$. **55** $\frac{57}{16}$. **56** $\frac{57}{16}$ of an inch. **57** $\frac{1680}{840}$. **58** $\frac{840}{120}$. **59** $\frac{12}{840}$. **60** $\frac{1}{7}$ of a pound. **61** 2. **62** 4. **63** 6. **64** 6. **65** $\frac{1}{2}$. **66** $\frac{3}{4}$. **67** 4. **68** 9. **69** $\frac{97}{11}$. **70** 25.

Chapter VIII, PROBLEM **1** $\frac{3}{75}$. **2** $\frac{27}{36}$. **3** $\frac{84}{96}$. **4** $\frac{125}{100}$. **5** $\frac{42}{120}$. **6** $\frac{1}{2}$. **7** $\frac{1}{2}$. **8** $\frac{1}{4}$. **9** $\frac{1}{3}$. **10** $\frac{1}{3}$. **11** $\frac{1}{3}$. **12** 5. **13** $\frac{1}{5}$. **14** $\frac{1}{5}$. **15** 5. **16** $\frac{1}{3}$. **17** 13. **18** $\frac{1}{13}$. **19** $\frac{12}{7}$. **20** $\frac{1}{3}$. **21** $\frac{1}{9}$. **22** $\frac{5}{11}$. **23** $\frac{9}{16}$. **24** $\frac{7}{9}$. **25** $\frac{63}{95}$. **26** $\frac{37}{53}$. **27** 11. **28** $\frac{25}{3}$. **29** $\frac{7}{18}$. **30** $\frac{27}{350}$. **31** $\frac{1}{11}$. **32** $\frac{5}{187}$. **33** $\frac{9}{4}$. **34** $\frac{23}{4}$. **35** $\frac{78}{11}$. **36** $\frac{120}{13}$. **37** $\frac{76}{7}$. **38** $\frac{157}{12}$. **39** $\frac{129}{5}$. **40** $\frac{1003}{100}$. **41** 3. **42** 3. **43** 4. **44** $1\frac{3}{4}$. **45** $3\frac{1}{3}$. **46** $3\frac{4}{5}$. **47** $9\frac{3}{16}$. **48** 5. **49** $99\frac{1}{7}$. **50** $8\frac{8}{9}$. **51** $2\frac{128}{561}$. **52** $15\frac{1}{2}$. **53** $16\frac{2}{3}$. **54** $13\frac{1}{3}$. **55** $7\frac{9}{13}$. **56** $22\frac{1}{2}$. **57** $14\frac{2}{5}$ ounces. **58** $58\frac{1}{2}$ grains.

Chapter IX, PROBLEM **1** 1. **2** $1\frac{3}{4}$. **3** $2\frac{1}{2}$. **4** $5\frac{1}{2}$. **5** 3. **6** $4\frac{1}{4}$. **7** $5\frac{1}{6}$. **8** $2\frac{35}{48}$. **9** $2\frac{2}{11}$. **10** $26\frac{23}{40}$. **11** $\frac{29}{160}$. **12** $\frac{131}{504}$. **13** $\frac{239}{630}$. **14** $\frac{513}{1400}$. **15** $21\frac{281}{780}$. **16** $13\frac{1}{2}$ pounds. **17** $46\frac{3}{4}$ pounds. **18** 46 pounds. **19** 46 pounds. **20** $55\frac{1}{2}$ hours. **21** 3. **22** $\frac{1}{2}$. **23** $\frac{1}{2}$. **24** $\frac{7}{8}$. **25** $1\frac{15}{16}$. **26** $\frac{1}{4}$. **27** $\frac{9}{16}$. **28** $7\frac{5}{9}$. **29** $20\frac{88}{95}$. **30** $18\frac{131}{180}$. **31** $5\frac{12}{31}$. **32** $7\frac{2}{9}$. **33** $418\frac{1}{2}$ pounds. **34** $5\frac{3}{4}$ pounds. **35** $1\frac{9}{16}$ inches. **36** $3\frac{7}{12}$ yards. **37** $43\frac{3}{4}$ ounces.

Chapter X, PROBLEM **1** $2\frac{1}{2}$. **2** 3. **3** $1\frac{3}{4}$. **4** $3\frac{1}{2}$. **5** $2\frac{1}{2}$. **6** 5. **7** $\frac{1}{2}$. **8** $\frac{1}{2}$. **9** $2\frac{1}{2}$. **10** $3\frac{3}{4}$. **11** 3. **12** 5. **13** 10. **14** $\frac{5}{28}$. **15** $13\frac{1}{3}$. **16** $1\frac{4}{5}$. **17** $4\frac{1}{2}$. **18** $27\frac{1}{4}$. **19** 3025. **20** 11,766. **21** $6\frac{3}{4}$. **22** $219\frac{41}{56}$. **23** (*a*) 14; (*b*) 11. **24** (*a*) 24; (*b*) 27. **25** 4000. **26** (*a*) 45;

(*b*) 40. **27** 98,175. **28** 44 pounds 11 ounces. **29** $\frac{3}{4}$ of a pound. **30** 890 dents. **31** 2000 pounds. **32** 189¢. **33** 2224. **34** $807\frac{1}{8}$. **35** $895\frac{1}{5}$. **36** \$24. **37** $8\frac{5}{14}$ pounds. **38** 471 pounds. **39** 216 pounds copper; 36 pounds tin; 9 pounds zinc. **40** 154 pounds water; 132 pounds tallow; 44 pounds starch; 88 pounds glycerine; 22 pounds ash.

Chapter XI, Problem **1** $\frac{3}{8}$. **2** $\frac{1}{4}$. **3** $\frac{1}{8}$. **4** $\frac{1}{8}$. **5** $\frac{3}{8}$. **6** $\frac{3}{8}$. **7** $\frac{3}{4}$. **8** $\frac{5}{8}$. **9** $\frac{5}{8}$. **10** $\frac{3}{4}$. **11** 1. **12** $\frac{1}{4}$. **13** $\frac{1}{4}$. **14** $1\frac{1}{4}$. **15** $\frac{3}{4}$. **16** $2\frac{1}{4}$. **17** $\frac{3}{4}$. **18** $\frac{7}{8}$. **19** $\frac{3}{8}$. **20** $\frac{5}{8}$. **21** $\frac{1}{4}$. **22** $\frac{3}{8}$. **23** $\frac{5}{16}$. **24** $\frac{5}{24}$. **25** $\frac{7}{80}$. **26** $\frac{9}{16}$. **27** $7\frac{2}{3}$. **28** $4\frac{1}{10}$. **29** $2\frac{117}{2200}$. **30** $1\frac{1}{4}$. **31** $2\frac{3}{8}$. **32** $1\frac{1}{4}$. **33** $2\frac{1}{8}$. **34** $5\frac{1}{7}$. **35** $6\frac{7}{24}$. **36** $4\frac{1}{50}$. **37** $1\frac{1}{100}$. **38** 2. **39** 4. **40** 16. **41** 24. **42** $2\frac{3}{8}$. **43** $2\frac{6}{7}$. **44** $2\frac{14}{17}$. **45** 8. **46** 90. **47** 14. **48** 2. **49** 2. **50** 6. **51** $\frac{1}{3}$. **52** 10. **53** $6\frac{1}{2}$. **54** $\frac{3}{14}$. **55** $\frac{91}{216}$. **56** $9\frac{1}{27}$. **57** $\frac{1}{2}$. **58** $15\frac{7}{8}$ pounds. **59** $\frac{3}{8}$. **60** (*a*) $2\frac{9}{16}$ inches; (*b*) 80 ends per inch. **61** $3\frac{11}{36}$ yards. **62** $52\frac{1}{4}$ grains. **63** 304 yards. **64** 32 hours. **65** $\frac{5}{16}$ pounds. **66** 64 yards. **67** 48 yards. **68** 10 days. **69** $6\frac{1}{4}$ days. **70** 20 frames. **71** $22\frac{2}{5}$. **72** $22\frac{1}{2}$.

Chapter XII, Problem **1** $\frac{9}{10}$. **2** $\frac{4}{5}$. **3** $\frac{7}{10}$. **4** $\frac{3}{5}$. **5** $\frac{1}{2}$. **6** $\frac{2}{5}$. **7** $\frac{3}{10}$. **8** $\frac{1}{5}$. **9** $\frac{1}{10}$. **10** $\frac{99}{100}$. **11** $\frac{49}{50}$. **12** $\frac{97}{100}$. **13** $\frac{91}{100}$. **14** $\frac{77}{100}$. **15** $\frac{3}{4}$. **16** $\frac{1}{2}$. **17** $\frac{9}{20}$. **18** $\frac{1}{4}$. **19** $\frac{11}{100}$. **20** $\frac{1}{10}$. **21** $\frac{9}{100}$. **22** $\frac{7}{100}$. **23** $\frac{3}{50}$. **24** $\frac{1}{20}$. **25** $\frac{1}{25}$. **26** $\frac{3}{10}$. **27** $\frac{1}{50}$. **28** $\frac{1}{100}$. **29** $\frac{999}{1000}$. **30** $\frac{499}{500}$. **31** $\frac{99}{100}$. **32** $\frac{977}{1000}$. **33** $\frac{4}{5}$. **34** $\frac{3}{4}$. **35** $\frac{1}{2}$. **36** $\frac{499}{1000}$. **37** $\frac{39}{100}$. **38** $\frac{1}{4}$. **39** $\frac{101}{1000}$. **40** $\frac{1}{10}$. **41** $\frac{99}{1000}$. **42** $\frac{81}{1000}$. **43** $\frac{3}{40}$. **44** $\frac{1}{20}$. **45** $\frac{1}{40}$. **46** $\frac{1}{100}$. **47** $\frac{9}{1000}$. **48** $\frac{1}{200}$. **49** $\frac{1}{1000}$. **50** $\frac{9}{10000}$. **51** 10.1. **52** 12.2. **53** 25.29. **54** 1.84. **55** .5. **56** 7.05. **57** 19.08. **58** 2000.0202. **59** .5. **60** 7.50. **61** 8.402. **62** 80.4. **63** 99.7. **64** \$5.01. **65** \$6.66. **66** \$1.59. **67** \$2.69. **68** \$22.89. **69** \$28.07. **70** \$557.11. **71** \$1906.06. **72** \$10.105. **73** \$19.199. **74** \$10 or \$10.00. **75** \$90 or \$90.00. **76** \$10,596 or \$10,596.00. **77** $10\frac{1}{2}$ cents. **78** $10\frac{1}{2}$ cents. **79** 14 dollars 56 cents. **80** 5146 dollars 56.7 cents. **81** 16.22. **82** 102.009. **83** 162.169. **84** \$280.35. **85** \$420.42. **86** .1760 pound. **87** 4.121. **88** \$.95. **89** .1091. **90** .0618 pound. **91** \$17.28. **92** 2.08 pounds.

Chapter XIII, Problem **1** 6. **2** 15.54. **3** 15.0953. **4** 174.328. **5** 2690.35695. **6** 3.927. **7** 27. **8** 81. **9** 1. **10** 1. **11** .0001. **12** .008. **13** .01. **14** .0001. **15** 10,000. **16** 10,000. **17** 5200. **18** 314.16. **19** 437,500. **20** 20. **21** 83. **22** 70. **23** 5.2. **24** .031416. **25** 7. **26** .00084. **27** 76.92. **28** .00120. **29** 2392.5 pounds. **30** 13,158.75 pounds. **31** 1247.5 pounds. **32** 10,180.5 pounds. **33** 950.4 pounds. **34** 1320 pounds. **35** 57.5 pounds.

36 62.5 yards. **37** 891 dents. **38** 1740 threads. **39** 1050.625 yards. **40** 120,300 knots. **41** 121 teeth. **42** $48.72. **43** $1600. **44** $3412.50. **45** $973.94. **46** $21.32. **47** $15.24. **48** $3.00. **49** $937.50. **50** $46.88. **51** $187.00. **52** $8.23. **53** $135.90. **54** $1262.50. **55** $100.49. **56** $1856.25. **57** $7.85. **58** $18.12. **59** $15.13. **60** $21.16.

Chapter XIV, PROBLEM **1** 2.50. **2** 3.33. **3** 6.25. **4** 16.67. **5** 66.67. **6** .125. **7** .25. **8** .5. **9** .625. **10** .75. **11** .875. **12** 1.125. **13** 1.25. **16** 28.17. **17** 1.27. **18** .134. **19** .069. **20** 45 days. **21** 1120. **22** 20.25 pounds. **23** 4.5 yards. **24** 15 belts. **25** 14 minutes. **26** 400 straps. **27** 640 pickers. **28** 35 inches. **29** 22.8 dents. **30** 1407.6 yards. **31** 72 pieces. **32** 25.83. **33** 47.9¢. **34** .4025¢. **35** $2.38. **36** 2.35¢. **37** 1.07 cuts. **38** 2.4 cuts. **39** 1.07 cuts. **40** 31.73 cuts. **41** 26 weeks.

Chapter XV, PROBLEM **1** 78.1 pounds. **2** 870.47 yards. **3** 640. **4** 330 yards. **5** 768. **6** 375. **7** 2631.6 pounds. **8** 3.56 yards. **9** 69.44. **10** 107,527 pounds. **11** $156.25. **12** $109.38.

Chapter XVI, PROBLEM **1** $6.05. **2** 24,011 yards. **3** 29.355. **4** 437.5 pounds. **5** 90%. **6** 80%. **7** .5%. **8** .8%. **9** (*a*) .5%; (*b*) .55%. **10** 96%. **11** 5%. **12** 15%. **13** $12\frac{1}{2}$%. **14** $12\frac{1}{2}$%. **15** 4.8%. **16** 8.3%. **17** 126,303 pounds. **18** 5460 pounds. **19** 49.6 yards. **20** 152.8 pounds. **21** 12.5. **22** 64.2 yards. **23** 38.3 inches. **24** 7.7%. **25** 5%. **26** Seconds, 18,948.6; shorts, 7105.7; firsts, 447,659.7. **27** Water, $994\frac{1}{2}$; tallow, 867; starch, $229\frac{1}{2}$; glycerine, $433\frac{1}{2}$; ash, $25\frac{1}{2}$. **28** 60%. **29** 918 bales. **30** 294 sheeting; 336 drills; 210 sateens. **31** 12 fixers. **32** 59.78 yards. **33** $5.00. **34** 325 yards. **35** 128.6%.

Chapter XVII, PROBLEM **1** 437.5. **2** 7. **3** 600. **4** 63 yards $25\frac{3}{16}$ inches. **5** 58 yards $30\frac{5}{8}$ inches. **6** 18 hours 21.6 minutes. **7** 25 lbs. 11.2 oz. **8** 7560 inches. **9** 19,250 grains. **10** 9240 yards. **11** 2.55 hours. **12** $10\frac{2}{3}$ yards, or 10.67 yards. **13** $9\frac{7}{16}$ lbs., or 9.44 lbs. **14** 2 lbs. 12 oz. **15** 7 yards 24 inches. **16** 5 hours 5 minutes. **17** 7.5 lbs. **18** 9.25 lbs. **19** 9.33 hanks. **20** 15.5 hanks. **21** 570 lbs. **22** 34 lbs. 7 oz. **23** 583′ 5″. **24** 454 lbs. 15 oz. **25** 3 hours 25 minutes. **26** 110 yards 32 inches. **27** 242 feet. **28** $1722\frac{1}{4}$ lbs. **29** 15 yards 16-oz. cloth; 19 yards 12 inches 12-oz. cloth. **30** 3′ $6\frac{1}{4}$″. **31** 3.1416″. **32** 6.2832″. **33** 392.7 inches. **34** 5.6942 yards. **35** $7\frac{1}{2}$″. **36** 5′. **37** (*a*) 6′; (*b*) $2\frac{1}{2}$″. **38** 42″ dia. **39** 9.

40 16. **41** 81. **43** 100. **44** 144. **45** 324. **46** 144. **47** 1296. **48** 1746. **49** 181.5. **50** 72. **51** 9. **52** $1957\frac{1}{2}$. **53** $11\frac{2}{3}$. **54** 1056. **55** $28\frac{1}{2}$. **56** $1135\frac{1}{4}$. **57** $278\frac{2}{3}$. **58** 15.91. **60** 153.94. **61** (*a*) 63.6174 sq. ft.; (*b*) 91,609.06 lbs. **62** 12.5664 sq. ft. **63** 1296 cu. in. **64** 1728. **65** 2 gallons. **66** 7.48 gallons. **67** 90 gallons. **68** 432 gallons. **69** 254 cu. ft. **70** 10,500 lbs. **71** 409.625 cu. ft. **72** 54.55 in. **73** 54.978 sq. ft. **74** 62,832 sq. ft. **75** 155.509 sq. ft. **76** 158.63 gallons. **77** 282 lbs. **78** 1451.42 gallons.

Chapter XVIII, PROBLEM **1** 5. **2** 6. **3** 7. **4** 8. **5** 9. **6** 10. **7** 11. **8** 12. **9** 9.75. **10** 17.00. **11** 21.25. **12** 16.25. **13** 2.4. **14** 1.2. **15** $1\frac{1}{3}$. **16** $1\frac{1}{4}$. **17** 1. **18** $\frac{3}{4}$. **19** $\frac{2}{3}$. **20** $\frac{3}{5}$. **21** $\frac{1}{2}$. **22** $\frac{1}{4}$. **23** .1. **24** .3. **25** .4. **26** .9. **27** 1. **28** Less. **29** Greater. **31** 15. **32** 16. **33** 21. **34** 35. **35** 105. **36** .93. **37** 2.94. **38** .89. **39** 35.23. **40** 15.37. **41** 17.97. **42** 4.0308. **43** 4.3008. **44** 4.5550. **45** 5.6418. **46** 6.5520. **47** .44721. **48** .42426. **49** 12.49. **50** 1.19583.

Chapter XIX, PROBLEM **12** 8720 lbs. **13** 2334.72 hanks. **14** 2356.2 lbs. **15** 5880. **16** 52 yards. **17** 12,845.5 lbs. **18** 92.5%. **19** $14.85. **20** 120 hours. **21** 18,544 yards. **22** 48 hours. **23** $21.60. **24** $18\frac{3}{4}$¢ per cut. **25** 40.8 yards. **26** 253 yards. **27** 50 hours. **28** 1728 ends. **29** 1.923 yards per lb. **30** 36.17″. **31** $18\frac{1}{12}$¢. **32** 28¢. **33** 4704 spindles. **34** 21.37 lbs.

Chapter XX, PROBLEM **1** 140.625 R.P.M. **2** (*a*) 35.6″; (*b*) $35\frac{1}{2}$″. **3** $\text{dia. of } B = \dfrac{\text{dia. of } A \times \text{R.P.M. of } A}{\text{R.P.M. of } B}$. $\text{R.P.M. of } B = \dfrac{\text{dia. of } A \times \text{R.P.M. of } A}{\text{dia. of } B}$. **4** 16.5″ dia. **5** 9.23″ dia. **6** 4523.9 feet per minute. **7** 746.13 inches per minute. **8** 7.64 R.P.M. **10** 4800 R.P.M. **11** 288 R.P.M. **12** 12″ dia. **13** 35″ dia. **14** Directly. **15** Directly. **16** Inversely. **17** Reduced $\frac{1}{2}$. **18** Tripled. **19** Opposite. **20** 11. **21** 1. **22** Inversely. **24** 104 R.P.M. **25** 42 teeth. **28** No effect. **30** $F = \dfrac{\text{S.S. of } I \times C \times H \times \text{dia. of } A}{\text{S.S. of } A \times B \times \text{dia. of } I}$. **31** 24 teeth. **32** 17 teeth. **33** No. **34** No. **35** No. **37** No. **38** (*a*) directly; (*b*) inversely; (*c*) directly; (*d*) neither; (*e*) inversely; (*f*) directly; (*g*) directly. **39** $\text{S.S. of } I = \dfrac{\text{dia. of } E \times F \times \text{dia. of } I \times 3.1416 \times \text{R.P.M. of } E}{\text{dia. of } D \times H}$. **40** $\text{S.S. of } A = \dfrac{\text{dia. of } E \times C \times \text{dia. of } A \times 3.1416 \times \text{R.P.M. of } E}{\text{dia. of } D \times B}$. **41** 471.24

inches per minute. **43** 27′ 10¼″. **44** 22′ 5″. **47** (*a*) 266.67; (*b*) 257.14. **48** (*a*) 266.67; (*b*) 266.12. **50** 26′ 6¼″. **53** (*a*) 5 tons; (*b*) .01″. **54** 21 lbs. **55** 5 lbs. **56** 24″. **57** 4″. **58** 3.8″, or $3\frac{13}{16}$″. **59** 12″. **60** 11.11″, or $11\frac{1}{8}$″.

PART TWO

Chapter I, PROBLEM **1** 4s. **2** 10s. **3** 100s. **4** 2s. **5** 1s. **6** 4s. **7** 1s. **8** 10s. **9** 50s. **10** 20s. **11** 100s. **12** 1s. **13** 12 HR. **14** 10 HR. **15** 5 HR. **16** 2 HR. **17** 1 HR. **18** .50 HR. **19** .25 HR. **20** .20 HR. **21** 10 HR. **22** 5 HR. **23** 4 HR. **24** .20 HR. **25** .25 HR. **26** 1 HR. **27** 2 HR. **28** .50 HR. **29** 30. **30** 9. **31** 5. **32** .5. **33** 2. **34** 5. **35** 1. **36** $\frac{3}{5}$. **37** 8. **38** $\frac{3}{50}$. **39** 1. **40** 1. **41** 1. **42** $\frac{1}{10}$. **43** 1. **44** 8400. **45** 50,400. **46** 420,000. **47** 23.86. **49** .2 HR. **50** .25 HR. **51** .5 HR. **52** 1 HR. **53** 2 HR. **54** 4 HR. **55** 8 HR. **56** 10s. **57** 20s. **58** 25s. **59** 40s. **60** 50s. **61** 100s. **62** 200s. **63** 19.23s. **64** 32s. **65** 4 HR. **66** 8.51 HR. **67** 3.90 HR. **68** 27.77 grs. **69** 23.52 grs. **70** 50s. **71** 25s. **72** 20.32s. **73** 14.28s. **74** 4.17 grs. **75** .69 grs. **76** 400 grs. **77** 9 yds. **79** 23s. **80** 13.02s. **81** 21s. **82** 13s. **83** 21.01s. **85** 20,185.22 yds. **86** 27,314.48 yds. **87** 26,553.83 yds. **88** 12,218.32 yds. **89** 33,516 yds. **90** 24,150 yds. **91** 23,520 yds. **92** 1248 yds., 1.49 hanks. **93** (*a*) 5376 yds.; (*b*) 13,440 yds. **94** 1680 yds., 2 hanks. **96** 559.82 lbs. **97** 555.84 lbs. **98** 491.71 lbs. **99** 2 lbs. **100** 1.64 lbs. **102** 360. **103** 330. **104** 360. **105** 75 lbs. **106** 96 lbs.

Chapter II, PROBLEM **1** 5. **2** 10. **3** 17.5. **4** 7. **5** 20. **6** 16. **7** 15. **8** 14. **9** 10. **10** 4.33. **11** 13.75. **12** 12.8. **13** 16.21s. **14** 14.58s. **15** 12s. **16** 18.94s. **17** 14.29s. **18** 9.63s. **19** 25.53s. **20** 18.46s. **21** 13.64s. **22** 8.05s. **23** 30s. **24** 43.04s. **25** 28.8s. **26** 75s. **27** 50s. **28** 40s. **29** 30s. **30** 100s.

Chapter III, PROBLEM **1** 4.25. **2** 4.01. **3** 4.13. **4** 4.7. **5** 108.44. **6** 105.16. **7** 99.65. **8** 100.79. **9** 5.62. **10** 5.38. **11** 5.29. **12** 4. **13** 4.5. **14** 4.76. **15** 4.17. **16** 3.07. **17** 6. **18** 6. **19** 6.06. **20** 6.18. **21** 7.02. **22** 13.33. **23** 7. **24** 7. **25** 55.26 grs. **26** 47.03 grs. **27** 12.10 oz. **28** 11.65 oz. **29** 10.25 oz. **30** 11.31 oz. **31** 10.49 oz. **32** 55.2 grs. per yd. **33** 53.26. **34** 64 grs. **35** 46 grs. **36** 59 grs. **37** .64 HR. **38** .625 HR. **39** 58.23 grs. **40** 60 grs. **41** 1.79 HR. **42** 1.82 HR. **43** .651 HR. **44** .88 HR. **45** .771 HR. **46** .80 HR. **47** 3.2 HR. **48** 6.4 HR. **49** 2 HR. **50** 2 HR. **51** 1.786 HR.

Chapter IV, Problem 1 7.4. **2** 8.4. **3** 9.3. **4** 18.6. **5** 60. **6** 112. **7** 150. **8** 212. **9** 242. **10** 300. **11** .108; .0067; .0055. **12** .033; .0047; .0027. **13** About 98. **14** .6. **15** .85. **16** 1.2. **17** 2.4. **18** 9.5. **19** 14.53. **20** 26.02. **21** 20.55. **22** 12.32. **23** 15.55. **24** 42.50. **25** 12. **26** 20. **27** 24. **28** 30. **29** 4. **31** 40s. **32** 40.9 or 41s. **33** 2/42.9 or 2/43s.

Chapter V, Problem 1 $3\frac{1}{5}$ oz. **2** $\frac{5}{9}$ lbs. **3** $933\frac{1}{3}$ grs. **4** 700 grs. **5** $530\frac{1}{3}$ grs. **6** $3\frac{5}{9}$ oz. **7** 25,000 lbs. **9** 2.529 yds. per lb. **10** 4.167 yds. **11** 4.321 yds. **12** 6.696 yds. **13** 1.658 yds. **14** 6.944 yds. **15** 1780 ends. **16** 2250 ends. **17** 224 ends. **18** 1836 ends. **19** 1916 ends. **20** 714 dents. **21** 912 dents. **22** 800 dents. **23** 5.1%. **24** 4.3%. **25** 4.4%. **26** 31.02″. **27** 43.478″. **28** 20.9. **29** 841. **30** 826. **31** 1366. **32** 1792. **33** 880. **34** 31.8″. **35** 38.4″. **36** 35.8″. **37** 38.5″. **39** 853.33 grs. **40** 492 grs. **41** 530 grs. **42** 6.29 lbs. **43** .47484 lb. **44** 5.4711 lbs. **45** 20.2381 lbs. **46** 7.7%. **47** 5013.05 yds. **48** 5654.45 yds. **49** 8696.87 yds. **50** 6753.19 yds. **51** 65.85 yds. **52** 61.88 yds. **54** 1.2658 lbs. **55** 15.68 lbs. **56** .5658 lb. **57** 202.78 oz. **58** 3.642 yds. per lb. **59** 5.13 yds. per lb. **60** 26.5s. **61** 16.2s. **62** 26.34s. **63** 72.36 picks per in.; about 72 or 73. **64** (*a*) 39.8%; (*b*) 60.2%.

Chapter VI, Problem 1 1.93. **2** 1.97. **3** 1.87. **4** 5867 lbs. **5** 3399 lbs. **6** 2233 lbs. **7** 12″ in diameter. **8** $6\frac{1}{2}$″ in diameter. **10** 5.629. **11** 3.602. **12** 2.251. **15** $P = 42$, $C^2 = 48$. **16** $C^2 = 45$, $P = 45$. **17** $dng = 41$, $drg = 49$. **18** $dng = 45$, $drg = 45$. **19** $dng = 40$, $drg = 50$. **20** $dng = 40$, $drg = 50$. **21** $dng = 36$, $drg = 54$. **22** 2.865. **23** 7.076. **24** 5.714. **25** 5.25. **26** 3.252. **27** 4.30. **28** 4.10. **29** 5.5. **30** 4.379. **31** 4.926. **32** 4.926. **33** $dng = 43$, $drg = 47$. **34** $dng = 47$, $drg = 43$. **35** Both gears 45 teeth. **36** $dng = 42$. **37** $dng = 53$. **38** $dng = 50$. **44** 1. **45** (*a*) 50; (*b*) 36; (*c*) 30; (*d*) 60. **46** 57. **47** 40. **48** 50 or 51. **51** .0295. **52** 1925 lbs. **53** $5\frac{1}{2}$″ diameter. **54** 91.3%. **56** 3.086. **57** 4.647. **58** 14.523. **60** 2.20. **61** 1087.5 R.P.M. **63** 65.82. **64** 21.18. **67** 5″. **68** 4″. **69** 68.04. **70** 69.02. **71** 70.23. **72** 68.2. **74** 1011.595. **75** 1068.144. **76** 1172.864.

Chapter VII, Problem 2 53.5. **3** 160.5. **4** 113.7. **5** 230.0. **8** 17. **9** 15. **10** 20. **11** 17. **12** 15. **13** 20. **14** 18. **15** 27. **16** 20. **17** 25. **18** 160.5. **19** 89.2. **20** 57.3. **21** 158.26. **22** 111.1. **24** 1580.8. **25** 1686.0. **26** 1706.96. **27** 2187.40. **28** 2273.68. **29** 3221.05. **34** 16. **35** 12. **36** 15. **37** 16. **38** 20.

39 25. **40** 16. **41** 30. **43** 7.66. **44** 15.31. **45** 7.46. **46** 13.40. **48** 32-tooth. **49** 20-tooth. **50** 22-tooth. **55** .213. **56** .241. **57** 156 lbs. **58** 114 lbs. **59** 140 lbs. **60** 103 lbs. **61** 96%. **62** 96%. **63** 10.8 lbs. **64** 28-tooth. **66** 20-tooth. **67** 27-tooth. **68** 18-tooth. **69** 31-tooth. **70** 447.85.

Chapter VIII, PROBLEM **1** $dc = \frac{A \times J \times L \times N \times P \times \text{dia. cal. roll}}{B \times M \times O \times Q \times \text{dia. electric roll}}$. **2** 270.60. **3** 383.34. **5** (*a*) 6; (*b*) 8.34. **6** 47-tooth. **7** 223.29. **9** 45. **10** 36. **11** 45. **12** 61. **13** 68-tooth back roll change gear; 59-tooth draft gear. **14** 5 teeth. **15** 1. **16** 1.111. **17** 1.386. **18** 3.463. **19** 1.035. **21** 3.66. **25** 339.20. **27** .01065. **28** .01408. **29** 179 lbs. **30** 236 lbs. **31** 32%. **32** (*c*) 1.88 lbs. short; 2. 3.4% short. **33** 80.7%.

Chapter IX, PROBLEM **1** 175. **2** dc = draft $\times$ dg, $dg = \frac{dc}{\text{draft}}$, draft $= \frac{dc}{dg}$. **3** 34. **4** 4.244. **6** 190.89. **7** 45. **8** 40. **9** 37. **10** 30. **18** 37. **19** 39. **20** 46 or 47. **21** 27 or 28. **22** 39 or 40. **23** 1.086. **24** 3.659. **28** 32.69. **31** 41. **32** 125.96. **33** (*a*) $\frac{9}{100}$ of one twist. **34** 1.94. **37** 40. **38** 39. **39** 34. **40** 238.76. **42** 51. **43** 27. **44** 44. **45** 1470. **48** 21. **49** 36. **50** 42. **51** 47. **52** About 41. **53** About 38. **54** About 29. **55** 5 hrs. 31 min. **56** 33 hrs. 25 min. **57** 20.51, 56.40, 11.28. **58** 3.98, 7.96, 9.55. **59** 4.39, 4.94, 9.88. **60** 2.55, 1.59, 7.95. **61** 1.50, .656, 6.56. **62** 6140 lbs.

Chapter X, PROBLEM **2** 7.1. **3** 8.2. **4** 8.16. **5** 6.15. **6** 7.05. **7** 8.77. **8** 35.15. **11** 55. **12** 46. **13** 61. **14** 49. **15** 55. **16** 46. **17** 20. **18** 66. **19** 21. **20** 15.96. **21** 20.22. **22** 30.87. **23** 986.70. **24** 1067.04. **25** 924. **28** 1051.96. **29** $tc = \frac{s \times f \times \frac{\text{R.P.M. } w}{\text{R.P.M. } cy}}{c \times \text{cir. } fr}$ **30** 1260.50. **31** 996.84. **32** 344.62. **33** 147.69. **34** 1422.10. **35** 878.53. **36** 413.09. **37** 166.93. **39** 5.7%. **40** 2.8%. **41** 5.4%. **42** .00%. **47** 35. **48** 43. **49** 50 or 51. **50** 34 or 35. **51** 36 or 37. **52** 45. **53** 34. **54** 55. **55** 40. **56** 25. **57** 31. **58** 33 or 34. **59** 71 or 72. **60** 10.67. **61** 12.13. **62** 12. **63** 9.33. **65** 54 or 55. **66** 45. **67** 32. **68** 40. **69** 38. **70** 50. **71** 41. **72** 25. **73** 9.26. **74** 10.24. **75** 12.98. **76** 320. **77** 264.60. **78** 434.70. **80** 3.6. **81** 416. **82** dc =

$\frac{C \times B \times \text{dia. of } fr}{F \times \text{dia. of } br}$. **83** 288.00. **84** 192.00. **85** 268.80. **86** 384.00. **87** 537.60. **88** 336.00. **89** 285.00. **91** 29. **92** 24. **93** 30 or 31. **94** 47 or 48. **95** 54. **96** 35. **97** 45. **99** 33. **100** 43. **101** About 48 teeth. **102** About 32 teeth. **103** About 39. **105** 1000 R.P.M. **106** 600 R.P.M. **107** 16″. **108** R.P.M. of $fr = \frac{c \times tg \times \text{R.P.M. of } cy}{s \times f}$. **109** 116 R.P.M. **110** 1316.9. **114** 6.07 hanks, .121 lb. **115** 8.03 hanks, .535 lb. **116** 97.0% production, 3.0% allowance. **117** 1787.06 lbs. **118** 1398.07 lbs. **119** 1226.5 R.P.M. **120** 50 hrs. 9 min.

Chapter XI, Problem 1 42. **2** 31. **3** 35. **4** 40. **5** 48. **8.** 2.84 lbs. **9** 83.7%. **10** 70.2 lbs. **14** 69-tooth. **15** 80-tooth. **17** (*a*) 3500 yds.; (*b*) 2. **18** 120 teeth.

Chapter XII, Problem 2 147.14. **3** Exactly 14.2″; ∴ $14\frac{1}{2}$″ pulley. **4** 133.44. **5** Exactly 13.34″; ∴ $13\frac{1}{2}$″ pulley. **6** 140.39. **7** 18. **8** 20. **9** 17. **10** 29. **11** (*a*) 18; (*b*) 45. **13** 47. **15** $\frac{K}{ppi} = \frac{W \times J \times M \times .975 \times \text{cir. } S}{2 \times H \times L} = \frac{1}{2} = pc.$ **16** 10. **17** 36 or 37. **18** $\frac{L}{ppi} = \frac{P \times H \times K \times M \times .975 \times \text{cir. } S}{2 \times G \times J \times O} = \frac{1}{2} = pc.$ **19** 14 or 15. **21** (*a*) 1; (*b*) 16. **22** (*a*) $\frac{3}{4}$; (*b*) 12. **23** $\frac{2}{3}$. **24** 1.80. **25** $K \times ppi = \frac{2 \times G \times J \times L \times O}{P \times H \times M \times .975} \times \text{cir. of } S = 304.5 = pc.$ **27** 38. **28** 10. **29** 15. **30** 25. **32** 22 or 23. **33** 15. **35** 20. **36** 15. **37** $O = \frac{N \times \text{no. of harnesses}}{2}$. **38** 50 teeth middle step. **39** 45 smallest step. **40** 5 steps; teeth in N 30, 20, 15, 12, 10; $O = 30$. **42** 1.8″ throw. **43** Front harness: 2.72″ or about $2\frac{3}{4}$″ throw of cam; back harness: 3.09″ or about $3\frac{1}{8}$″ throw of cam. **44** Front harness: 2.34″ or about $2\frac{3}{8}$″ throw of cam; back harness: 3.26″ or about $3\frac{1}{4}$″ throw of cam. **45** (*a*) 3″; (*b*) 5 yds.; (*c*) 50 yds. **47** 56.94 yds. **48** 120.8 yds. **49** 43,670.5 yds. **50** 12,960 yds. **51** 428,868 yds. **52** 95,040 yds. **53** 94.98%. **54** 98%. **55** 44,993.88 yds. **56** 38.33 yds. **57** 100 looms. **58** 297,792 yds. **59** 93,552.38 yds. **60** 200 looms. **61** 100.22 cuts.